MEDICAL WAR MANUAL No. 4
MILITARY ORTHOPÆDIC SURGERY

PREPARED BY
THE ORTHOPÆDIC COUNCIL

MEDICAL DEPT. U.S.A.

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Authorized by the Secretary of War
and under the Supervision of the Surgeon-General
and the Council of National Defense

Military Orthopædic Surgery

U.S. Surgeon-general

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PREFACE TO SECOND EDITION.

In the second edition of this Manual only slight changes have been made. A few modifications in the stock splints, adopted either to increase their efficiency or decrease cost, have been noted and new working drawings inserted. Those features from the Manual of Splints and Appliances, issued by the American Expeditionary Force, which were placed in the Supplement of the first edition are now incorporated in the body of Chapter XI.

WASHINGTON, D. C., 1918.

PREFACE TO FIRST EDITION.

In the preparation of a manual for military use it seemed wise from every stand-point to profit by the experience of our Allies. We feel that no apology is necessary for the fact that we have quoted by permission very largely, and taken even whole chapters, from the writings of Col. Sir Robert Jones. Their unusual excellence and the wide experience of their distinguished author offer sufficient excuse.

The chapter on the prophylaxis of the foot has similarly been taken almost entirely from the excellent work of Colonel Edward L. Munson, U. S. A., on *The Soldier's Foot and the Military Shoe.*

We are greatly indebted to Mr. Harvey R. Pierce for valuable assistance in the matter of the specifications and illustrations for the splints.

Washington, D. C., 1917.

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MILITARY ORTHOPÆDIC SURGERY.

CHAPTER I.

THE HUMAN FOOT: ITS PHYSIOLOGY, EXAMINATION, AND THE SIGNIFICANCE OF ITS ABNORMALITIES.

Of the various activities of the orthopædic surgeon in military service none surpasses in importance the assistance rendered in the prevention of disability arising from foot affections. "It will not be disputed that the marching powers of foot troops are a most important factor in the conduct and success of battles and campaigns, and that the army which marches best, other things being equal, is the successful army." Hence, even relatively simple injuries of the feet possess very great practical interest from the military point of view, since they may rapidly render a large number of men unfit for service. The amount of disability from foot injury in modern armies is enormous; it has been estimated for European armies as an average loss of 10 per cent. among unseasoned troops on taking the field—as large a number as would be lost as the result of a pitched battle. A cause which operates—without any possible compensatory results—in practically every command to so reduce the number of those previously effective is worthy of the most careful study.

In the military service the examination of the foot is

made for two purposes: (1) To determine whether a foot will be able to meet the severe demands of military service, and (2) to efficiently care for the foot which has failed to meet these requirements while in service. In order to do this it is essential that the military surgeon have a thorough understanding of the following facts:

The human foot is an active organ of locomotion and not a passive support on which to stand and walk. A foot may be normal in appearance but functionally disabled; moreover, a foot may be structurally abnormal but capable of performing its function without suffering or disability. The bones of the foot are united, and the foot is united to the leg, by ligaments, which are joined to the bones through the medium of the periosteum. Ligamentous tissue is inelastic and itself not sensitive; periosteum, on the other hand, is richly supplied with sensitive nerves, and when subjected to stress, either excessive or long continued, becomes the seat of pain and eventually the seat of inflammation. When the element of infection is added, this pathological factor produces not only increasing disability but the development of a lesion which persists with its cause. When the muscles are acting normally the ligaments are thereby protected from undue stress and tension. If the muscles fall short in performing their function, the condition of ligamentous strain is induced, and from this results disability and eventually deformity.

The examination of the feet should be conducted with the view of determining whether the foot is normal or abnormal: (*a*) in appearance, (*b*) in action, and (*c*) whether by the examining hand there can be found causes for pain and disability.

THE NORMAL FOOT.

The appearance of the normal foot should be considered with regard to (*a*) the relationship of the foot to the leg,

(*b*) the appearance of the foot itself, and (*c*) the appearance of the arches of the foot.

Fig. 1.—The plumb line dropped from the crest of the tibia in a position almost normal.

(*a*) Relationship of the Foot to the Leg.—When viewed from the front a line drawn from the center of the patella downward to the crest of the tibia and continued over the foot should meet the interval between the second and third toe. When viewed from behind a perpendicular dropped from the center of the popliteal space, should pass through the middle of the heel.

(*b*) Appearance of the Foot Itself.—The toes should be straight, lie flat, and be capable of plantar flexion at the metatarsophalangeal joints. There should be free

Fig. 2.—The plumb line dropped from the center of the popliteal space in a foot with marked pronation of the ankle; the short black line indicates the center of the heel and the point where the plumb should coincide.

dorsal flexion of the great toe. A straight edge applied to the inner side of the heel and the inner side of the first metatarsophalangeal articulation should come in contact with the inner side of the great toe at its distal end.

(*c*) THE ARCHES OF THE FOOT.—The longitudinal arch is seen from the inner side of the foot; it extends from the heel to the distal end of the first metatarsal, and its highest

FIG. 3.—"Represents impressions taken with printer's ink, and reduced from the sole of a boy, aged eleven and a half years, in duplicate. The awkward look of a single sole print is not apparent when the two are seen together, the curves round the toes running into each other gracefully. The line (*a*) known as Meyer's line, is seen to run through the center of the heel and along the middle line of the great toe. A line (*b*) from the inner side of the heel to the inner side of the great toe will be found to pass clear of the joint at the root of the latter. The form of the area covered as by a dome or bell-shaped covering, when the two ankles are joined, is also evident." (After T. S. Ellis.)

point corresponds to the scaphoid bone. While a distinct arch should be present there is no established normal for its height. The transverse arch is formed by the distal ends of

the metatarsal bones, which should present a convexity when viewed from the dorsum of the foot, the highest point of the arch being made by the second and third metatarsals.

The action of the normal foot is determined by the movements which take place in (*a*) the ankle (tibio-astragaloid) joint, (*b*) the subastragaloid joint, and (*c*) the mediotarsal joint.

(*a*) THE ANKLE (TIBIO-ASTRAGALOID JOINT).—It should be possible to dorsal flex the ankle to an angle of 70 to 80 degrees. The test is made with the knee fully extended and the forefoot inverted, the angle being formed between the fibula and the outer border of the foot. Plantar flexion, measured in the same way, should be 130 to 135 degrees.

(*b*) THE SUBASTRAGALOID JOINT.—The motion at this point is chiefly in a lateral direction, but combined with some degree of rotation. The movement of the foot outward at this articulation is termed pronation; that inward is called supination.

(*c*) THE MEDIOTARSAL JOINT.—Here there is free movement in several directions, but especially toward the median line—adduction; reverse motion, abduction. The terms eversion and inversion should be reserved for movements of the whole foot pivoting on the heel. Such movements are produced above the ankle-joint.

DEVIATIONS FROM THE NORMAL.

Deviations from the normal are to be determined by (I) the changes in the appearance of the foot, (II) in its action, and (III) the presence of symptoms and other signs of foot abnormality.

I. CHANGES IN THE APPEARANCE OF THE FOOT.—(*a*) In the standing position the normal line of weight-bearing, as seen from the front, may be displaced inward by abduction of the forefoot, by pronation, or by the combination of them. This is to be considered of serious import, however,

only when the displacement is to the inner side of the great toe, and when taken into consideration with the other features. When seen behind, a perpendicular dropped from the middle of the popliteal space may pass to the inner side of the center of the heel by pronation; this likewise is to be similarly appraised in connection with the other features of the case.

(*b*) Deviation of the great toe toward the outer border of the foot (hallux valgus) is usually associated with a greater or less enlargement of the metatarsophalangeal joint or of the bursa over it (bunion). Rigidity of the great toe (hallux rigidus), when it interferes with dorsal flexion of the toe, seriously affects the marching capacity; loss of motion of this joint in the other directions is usually of less importance. Contracture of a toe at the middle phalangeal joint (hammer toe), when rigid, is usually associated with a corn on the dorsal surface of the joint; it may prove a disabling feature and so require surgical treatment. Enlargement of the ends of the toes (clubbed toes) is to be considered with reference to the possible formation of blister. A flexor contracture of the four smaller toes, plantarly at the middle phalangeal and dorsally at the metatarsophalangeal joint (claw toes), is usually associated with a high longitudinal arch, and when severe, producing a contracted (claw) foot, with many callosities, is very disabling. Overriding toes are to be examined particularly with regard to the presence or possible production of corns and blisters. Ingrown nails, most common on the great toe, must always be noted. Callosities are usually limited to the forefoot, and are of special importance when situated over the lateral aspect of the great and little toe-joints, and on the sole under the heads of the metatarsal bones, particularly the second.

(*c*) The straight inner edge of the foot is distorted by hallux valgus and by abduction of the forefoot. This line thus becomes convex inward.

II. Changes in the Action of the Foot.—(*a*) Limitation of dorsal flexion is most often due to a short tendo achillis. This is frequently present in weak and painful feet, and is a factor of considerable importance and should be considered in making a prognosis. Limitation of dorsal and plantar flexion is also often due to causes operative in the ankle-joint itself, such as infectious arthritis or tuberculosis.

(*b*) Limitation of motion in the toes may be observed in connection with (1) congenital deformities, or with (2) deformities and contractures resulting from improper use because of bad shoes, such as hallux valgus, hammer toes, extension contracture in connection with spreading of the anterior arch, hallus rigidus, and arthritis of the toe-joints.

(*c*) Pronation and abduction are most often associated in varying relations. Persistent pronation and abduction of the foot are abnormal. Flaccidity indicates insufficient control by the adductor and supinator group of muscles, therefore foot weakness and ligamentous strain. Loss of flexibility (rigidity) in the direction of adduction and supination may be due to joint disease (arthritis, tuberculosis, etc.), or to the effect of long-continued foot-strain, especially in the presence of infectious atria elsewhere in the body, in which case it is very likely associated with definite contracture or spasm of the peroneal group of muscles.

(*d*) Eversion of the feet may be considered to constitute an abnormal posture when the feet are used with a divergence of more than 30 degrees in standing, and when exceeding this is to be regarded as an element of possible harm. In walking, however, the gait should be with parallel feet.

III. The Presence of Symptoms and Other Signs of Foot Abnormality.—1. *Symptoms.*—In obtaining the history of the symptoms which may have been experienced it is especially desirable to encourage the patient to relate them without prompting rather than to call them forth by

specific questions. Complaints may be made of discomfort or disability (*a*) in the foot itself—as pain upon use, after long periods of use and upon rising in the morning, stiffness after a period of rest, or fatigue after use—and (*b*) at more remote points—as in the knees, thighs, hips, or lower spine.

2. *Signs* (additional to those already discussed).—On inspection careful attention should be paid to the general body posture as well as the special foot posture, the character of the gait and particularly as regards elasticity, the condition of the circulation, and the presence of hyperidrosis and bromidrosis. In palpation and manipulation one should determine the presence of exostoses on the dorsum of the foot and elsewhere, stiffness of the individual joints, and points of tenderness. Those points of tenderness of particular importance and whose presence or absence should be definitely determined are the following:

(*a*) The metatarsophalangeal joints, especially the second, and in the presence of a plantar callosity at this point.

(*b*) The tubercle of the scaphoid and the ligamentous attachments to the scaphoid.

(*c*) The inner projection of the sustentaculum tali, below the internal malleolus, at the attachment of the tibiocalcaneal ligament (symptom of supination weakness even in the absence of pronation deformity).

(*d*) The anterior tubercle of the os calcis.

(*e*) The tendons behind the external and internal malleoli.

(*f*) In the leg over the crest of the tibia and the belly of the tibialis anticus muscle.

The Relative Significance of the Symptoms and Signs.—Limitation of dorsal flexion to 90 degrees and less should be considered as a factor of potential weakness. It is important when associated with other abnormalities or with symptoms of strain. Except when present to a marked degree (90

degrees) it is not of itself disabling. It is to be remembered that this condition is remediable.

The limitation of plantar flexion of the metatarsophalangeal joints to less than full extension is of importance when associated with (*a*) permanent flexion of the phalangeal joints, (*b*) a resulting prominence of the plantar surface of the anterior arch, (*c*) in the presence of callosities on the plantar surface of the anterior arch. When associated with other abnormalities this condition becomes of decided importance.

Loss of dorsal flexion of the great toe is important, and in any degree is a disabling feature in the use of the foot in walking; when present in more than slight degree (hallux rigidus) it is disqualifying. Hallux valgus, if marked, or associated with exostoses or a bunion of any size, particularly when signs of irritation are present, is to be considered distinctly disabling.

Abduction and pronation are always to be regarded as potential factors of marked importance in producing disability when (*a*) present to the degree of causing the weight-bearing line to fall inside the lines of support of the foot, (*b*) when associated with rigidity of the foot in this region, (*c*) when accompanied by symptoms of strain; (*d*) it is disabling when associated with other abnormalities of the foot, such as deformity of the toes, etc., and particularly so when associated with pathological changes in the articulations.

Eversion or inversion of the foot in standing and walking (see definition) is not to be regarded as important, but as a posture defect which is remediable.

A low or even absent longitudinal arch is not of itself important, and when found in a foot otherwise practically normal in shape and flexibility is not to be considered disabling. It is important when associated with other abnormalities, such as the following (but it must be remembered that the disability is probably due more to the accompanying conditions than to the loss of the height of the arch): (*a*)

limitation of dorsal flexion, (*b*) rigid metatarsal and sub-astragaloid joints, (*c*) rigid and deformed toes, (*d*) pronation; (*e*) pain and tenderness, (*f*) prominent scaphoid, (*g*) arthritis, (*h*) edema and varicosities.

The transverse arch may be flattened in varying degree and is usually associated with the prominence of the plantar surface of this region, together with markedly diminished force of plantar flexion at the metatarsophalangeal joints even with rigidity of these joints in dorsal flexion. Obliteration of the transverse arch is of importance when associated with the following conditions: (*a*) permanent dorsal flexion of the small toes (claw toes), (*b*) prominence of the plantar surface of the anterior arch, particularly in the presence of callosities, (*c*) an abnormal flaccidity of the forefoot and toes, (*d*) when accompanied by severe painful symptoms.

CHAPTER II.

THE SOLDIER'S FOOT AND THE MILITARY SHOE; PROPHYLAXIS.

THE prevention of foot disability in the army involves the use of four measures:

1. The use of a correctly shaped and properly fitted shoe.

2. Proper attention to the feet themselves and to both shoes and socks.

3. Protection of the recruit from being overloaded and overtaxed, and special attention to the development of foot efficiency during the first few weeks of life in the training camp.

4. The detailing of all men presenting any suspicion of foot troubles, either present or potential, to squads for the special attention of the orthopædic surgeon.

1. THE USE OF A CORRECTLY SHAPED AND PROPERLY FITTING SHOE.—The present army shoe, made over the Munson army last, is most excellent, and will meet the requirements of all but a small number, probably not more than 1 or 2 per cent., who have feet widely divergent from the general type. It is well to have in mind that even when the shoe is properly fitted some difficulty may be experienced for a time, due to the change in shape from that which has been worn.

"The recruit will probably need two specially careful shoe-fittings, one as soon as he enters the service and a second one some six months later; it is a matter of observation of

the Shoe Board that the foot of a recruit put in the army shoe tends to broaden, thicken, and strengthen very materially after enlistment, through use of a broader last and the foot development resulting from marching and other exercise. A shoe somewhat different in width from that originally selected will very likely now be found to be desirable. But after the feet are once expanded and 'set,' further change of shoe will not be necessary and the man's shoe size becomes practically a constant quantity for future requisitions and trials.

After the military shoe has been fitted to the newly enlisted recruit the latter should not undertake hard marching in it for at least a fortnight. This requirement, for a shoe which is properly fitted, may seem strange. But the army shoe is built on a last quite different from that of the shoe which the recruit has worn until recently and to the shape of which his foot has become habituated and conformed by long use. The army last is broader, its shape is dissimilar, and its points of support are different from the ordinary civilian shoe. The result is that the foot of the recruit must be given time to adapt itself to its new covering. Its outline must be altered, new bearing surfaces must be toughened, and, most important of all, foot muscles hitherto weak and undeveloped must be strengthened to support ligaments now subjected to a greater and unaccustomed strain. It takes time, of course variable with the individual, to do all this; but until such alteration and improvement of the foot type have been accomplished, discomfort and dissatisfaction with the new shoe may be expected on hard marching."[1]

In the second fitting of the recruit with shoes, and in old soldiers, no such objections exist in respect to the immediate use of new shoes in the field, for the foot has by this time been changed in the above respects.

[1] All quotations except as noted are from Col. Munson's book.

In regard to the fitting of shoes, General Orders, No. 26, 1912, specifically states:

"All measurements prescribed herein will be taken with the soldier standing in bare feet and with a 40-pound burden on his back, bearing the entire weight upon the foot to be measured. Balance may be preserved by resting the hand on a fixed object. The measurements of the foot, which must be taken to make suitable preliminary selection of the shoe to try on, are (*a*) the length, and (*b*) the circumference around the ball.

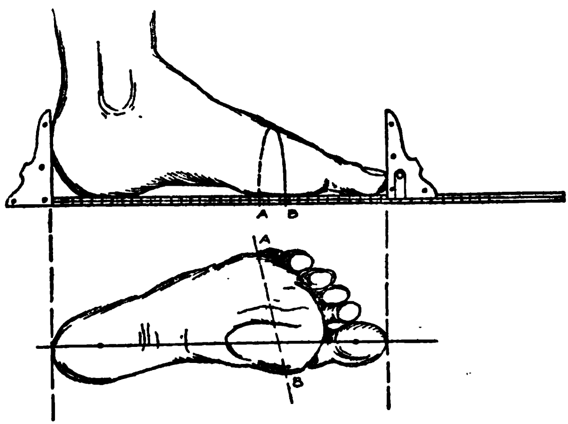

FIG. 4

To measure the length the soldier will stand with foot upon the foot measure, furnished by the Quartermaster's Department, fitted in a slot in a board, the heel of the soldier fitting snugly against the heel block. The movable block will then be pushed up until it touches the end of the great toe. The scale on the top of the measure, which is graduated

in sizes, will then be read, and the proper length of the shoe will be determined, approximately, by adding 2 to the reading of the scale; thus if the soldier's foot scales 6½, a shoe not smaller than 8½ should be tried on first.

To take the ball measure, pass the foot tape, supplied by the Quartermaster's Department, around the foot at the prominent tubercle at the base of the great toe and the prominent tubercle at the base of the little toe. The position of the tape is shown by the line *A–B* in Fig. 4.

The tape should lie closely to the flesh, but should not be so tight as to compress it. Having taken the foregoing measurements, the shoe best suited to the foot will be determined by reference to Circular No. 10, Quartermaster-General's Office, April 6, 1912. For example, assume that the circumference of the base is found to be 9½ inches. In the table on page 28 of the aforesaid circular, under the heading 'Marching Shoes,' it will be seen that for a foot requiring an 8½ shoe a ball measurement of 9¼ inches corresponds to a *D* width. The size of shoe to try on for actual fitting is, then, in this case, 8½ *D*.

If the ball measurement found as above does not correspond exactly with any ball measurement given in the table, then the narrower of the two widths between which the measurement lies should be selected.

Beginning with the size and width thus tentatively selected, shoes will be tried on until a satisfactory fit is secured. Correct fit in waist and instep will be determined experimentally. To determine the fact of fit the shoe will be laced snugly and the soldier with a 40-pound burden upon his back will again throw his entire weight on one foot. The officer will then press in the leather of the shoe in front of the toes to determine the existence of sufficient vacant space in that region to prevent toe injury. Under no circumstances should this vacant space in front of the great toe be less than two-thirds inch; nor should there be pressure on the top of the

toes. The officer will then grasp with his hand the leather of the shoe over the ball. As his fingers and thumb are brought slowly together over the leather the shoe should feel snugly filled without apparent tension, while the leather should lie smoothly under the hand. If the leather wrinkles under the grasp of the hand the shoe is too wide and a narrower width is needed; if the leather seems tense and bulging and the hand tends to slip over easily the shoe is too narrow and a greater width is necessary.

It may be necessary to try on several pairs of shoes in this manner before an entirely satisfactory shoe is secured. A record of the proper size and width of shoes as determined above will be kept as provided in Circular No. 10, Quartermaster-General's Office, April 6, 1912.

Measurements will be taken and shoes will be fitted as prescribed at least once in each enlistment and the record will be changed from time to time if subsequent fittings render a change necessary.

Sizes called for in requisitions will conform to the record, and the fact of fit of shoes issued on such requisitions will be personally verified in every instance by company commanders in the manner above prescribed.

No shoes will be issued to or worn by enlisted men while on duty which are not fitted in accordance with this order.

New shoes should be adapted to the contours of the feet as soon as possible. Shoe stretchers, with adjustable knobs, to take pressure off painful corns and bunions, are issued by the Quartermaster's Department.

All shoes should be properly broken in before beginning a march, but if this is impracticable then the following is suggested but not required:

The soldier stands in his new shoes in about 2½ inches of water for about five minutes until the leather is thoroughly pliable and moist; he should then walk for about an hour on a level surface, letting the shoes dry on his feet, to the irregu-

larities of which the leather is thus molded in the same way as it was previously molded over the shoe last. On taking the shoes off a very little neat's foot oil should be rubbed into the leather to prevent its hardening and cracking."

2. Proper Attention to the Feet Themselves and to Both Shoes and Socks.—*What is Expected of Line Officers.*—"So long as infantry is the backbone of an army, and mobility is the most important element in strategy, frequent careful inquiry into the condition of the feet, and constant interested oversight looking to their continued welfare, are properly to be required of all officers concerned. This duty is not always congenial, but the same is true of various other necessary things connected with the military service. And probably no one thing will more conduce to greater marching radius, the success of tactics, and the delivery on the firing line of the maximum number of rifles than will proper foot care of the command. Conversely, neglect in this respect produces a vast amount of military inefficiency.

The remedying among their men of minor defects, like their prevention, largely falls within the province of organization commanders as being part of the ligitimate internal administration of the company. For this duty no more technical knowledge is required than may properly be expected of all officers with foot troops. Only in relatively few cases should the professional advice and assistance of the surgeon be required, when the company officer possesses and applies a reasonable and proper knowledge as to foot conditions and foot care. The view that minor defects should habitually be treated by the surgeon is quite incorrect.

If the company commander gives due care to the careful fitting of shoes of newly arrived recruits, and repeats this in a few months when their feet have altered in shape and developed in size and strength, as a result of the use of the physiological army shoe and practice in marching under burden-carrying, he will probably subsequently need to give

his men little further attention in this respect other than to see that they fit on and draw the size and width with which they were last fitted, and counteract the general tendency to secure a shoe too small for the needs of the foot in marching.

But he must verify, by frequent foot inspection, the fact that the shoes thus selected really do fit, and at the same time he should give such simple, common-sense directions as should result in the relief or removal of the ordinary foot defects. For the making of these foot inspections, as with the routine examination of animals on the picket line, the presence of the surgeon and veterinarian, as already mentioned, is unnecessary. Only in a very few instances will medical advice and assistance be required, and these doubtful cases should be sent to the surgeon for examination.

The necessary frequency of foot inspection is variable with conditions. In barracks, when men are marching but little, one such inspection every fortnight should meet all needs. But in the field, or when troops are undergoing hard marching, such inspections should be made daily, that trifling defects and injuries may be given prompt attention and thereby prevented from developing into matters of importance.

The time required to make the foot inspection of a company is not to exceed half an hour, and as officers and men become accustomed to the routine it may be shortened to half that time. For two officers of a company working independently, such an inspection is a matter of only a few minutes. Never under any circumstances does it approach in duration the time required for the 'Stables' held twice a day by a mounted command.

The inspection is made after the feet have been washed; in many cases it is combined with the general inspection of the person required by regulations. In garrison the men stand in bare feet at the foot of their bunks until the officer has passed them by; in the field, they sit on the ground in front of their tents, or at such other convenient place as may

be required. As the officer passes, accompanied by the non-commissioned officer in charge, he notes the condition of the feet, especially in regard to recent injury, but also with reference to old remediable defects. In case attention to the feet is needed, he gives appropriate directions to the soldier in the presence of the non-commissioned officer, who becomes responsible for their being carried out."

"Before a march is undertaken by foot troops, company commanders will personally inspect the bare feet of their men. While on the march they will personally see each day that their men wash their feet as soon as possible after reaching camp, prick and evacuate blisters, and cover such blisters or excoriations with zinc oxide plaster, supplied by the Medical Department, applied hot, dust the feet with the foot powder supplied by the Medical Department, and put on clean socks. Hereafter an undue amount of foot injury and disability from shoes will be regarded as evidence of inefficiency on the part of the officers concerned and as causes for investigation." (General Orders No. 26, 1912.)

Care of Shoes.—*Oiling*.—The sole and welt of the shoe should be well oiled to keep the leather supple and prevent absorption, but on the upper only just sufficient oil should be used in dry weather to keep the leather supple, as heavy oiling of the upper interferes with evaporation of perspiration, thus causing the feet to be constantly hot and sweaty in warm weather (much as in rubber boots); but when constant exposure to wet is anticipated, heavy oiling may be used. (Neat's foot oil may be obtained from the Quartermaster's Department, or bacon rind, which is first soaked in water to remove the salt, may be used.)

Drying.—Shoes must always be carefully dried when removed for the night, as otherwise they will get out of shape and wrinkles form in the leather, which are apt to produce blisters and excoriations. Rapid drying hardens the leather and so must be avoided; when speed is necessary,

clean pebbles may be slightly heated in the mess tin, put into the shoe, and shaken about until inside moisture has been driven off; or hot, dry cloths may be stuffed into the shoes and if necessary, reheated; or the shoes may be packed with dry oats and left overnight, but in this case care must be taken to get all the oats out. When nearly dry, the shoes should be thoroughly brushed or rubbed to remove all dirt and soften the leather. If the upper is stiff after drying, the leather should be well worked with the hand and oiled lightly. Shoes must be protected from dampness during the night and *this is especially important in the winter to prevent moist leather from freezing;* if damp, they should not be used in the field as a head rest at night. The inside of the shoe should be wiped out occasionally with a dry cloth.

Incidentals.—The soldier should examine the inside of his shoes regularly, for wrinkles, nail points and other uneven places and should correct them at once. Broad shoe laces should be used and the shoe be always properly laced; a badly laced shoe on a march will almost certainly cause foot injury.

Care of Socks.—The regulation light wool sock is preferable and is the one that should be worn when the shoes are fitted; if the heavy wool sock is to be worn (in cold weather), a larger shoe will be required. Too small socks cramp the toes; if much too large, the wrinkles may produce blisters and excoriations.

Socks used in marching should be free from holes and from darning, and must be clean. Ordinarily they should be washed immediately after washing the feet. After washing and rinsing, they should be dried thoroughly and then stretched before using. If not possible to wash them, they can at least be changed and the dirty ones dried and thoroughly beaten and worked with the hands to remove dirt and hardness before being put back in the pack. It is also well to change the socks from one foot to the other.

3. Protection of the Recruit from being Overloaded and Overtaxed, and Special Attention to the Development of Foot Efficiency during the First Few Weeks of Life in the Training Camp.—"If an untrained recruit—and particularly one in whom a previous sedentary occupation has not resulted in fair foot development—be suddenly made to carry the military burden and undertake a hard march, this physiological balance, as adjusted for different conditions, may be disturbed, and the feet suffer an injury which may be permanent. It is particularly important to remember this fact at recruit depots and in the raising of volunteer troops, when there is every incentive to transform the civilian into the soldier in the shortest possible time—for misdirected energy in this respect may result in promptly spoiling many of what might otherwise be developed into excellent soldiers."

While this therefore depends very largely upon the judgment of the commanding officer, it is still influenced to no small degree by the surgeon, who should, at the time of his examination of the recruits, be particularly careful to note all those presenting evidence of potential foot weakness and to recommend them for special preliminary training or for treatment when necessary.

It will prove of great advantage in the development of foot efficiency to include the following exercises in the regular foot drill, at least for the first few weeks of camp life: (1) Rising on the outer border of the feet, (2) rotating the legs outward, and (3) toe clinching (can be done with shoes on). These are explained in the list of exercises given later.

4. Special Attention for Those Presenting Evidence of Foot Abnormalities Either Present or Potential.—Such may be divided into three groups:

(*a*) Muscular insufficiency.

(*b*) Abnormal foot posture.

(*c*) Milder defects susceptible of correction by mechanical or relatively simple surgical measures.

(*a*) *Muscular Insufficiency.*—Coming as they do from all walks of life, we may expect to find many recruits with structurally good feet, but with muscular development which, while sufficient for their needs in a sedentary occupation, is yet considerably below the average. Such men, if subjected to the regular routine, will soon be incapacitated; they should be detailed to special squads for more gradual course of training and more careful supervision by the surgeon.

(*b*) *Abnormal Foot Posture.*—It is true that abnormal foot posture may exist without having produced symptoms, the muscular development having been good and the load not excessive, yet such defects in the soldier must be looked upon as a potential source of disability and should receive special attention. Since no possible harm can result from the correction of such defects by muscular training, all recruits presenting them, even if of apparently slight degree, should be given the benefit of the training. The most common deviation from the normal foot posture is naturally that of pronation and abduction which is to be regarded as the prodromal stage of flat-foot.

The instruction in these cases must be given *individually as well as in squads*. The mechanism of the foot should be explained, the proper method of walking taught and exercises used to restore tone to the insufficient muscles.

Many exercises are available for muscle training in weak feet and no doubt all can be so used as to be beneficial; of chief importance, however, is the care with which the exercises are performed. By using a minimum number of exercises, carefully explaining what each is intended to accomplish, and seeing that each one is performed in exactly the proper manner, one can expect to secure the greatest benefit in the shortest time. The muscle groups especially

to be considered in weak feet are the adductors of the foot, the small muscles of the sole, and the outward rotators of the hip. Owing to the restricting influence of modern foot coverings, the long muscles controlling the forefoot and the intrinsic muscles of the foot are usually very poorly developed and are proportionately very much weaker than the calf muscles. In the selection of any group of exercises, therefore, they require particular attention. This is especially the case in high-arched feet in which the proper development of the intrinsic foot muscles with the consequent thickening fills out the excessive hollowness of the foot and thus increases the weight-bearing surface. The outward rotators of the hip have also not received the attention they deserve; in the opinion of some they are the muscles most concerned in the correction of pronation. When possible, these exercises should be performed with bare feet.

The following list of exercises will suffice for all except special cases:

1. Rising on the outer borders of the feet: stand with the feet parallel and rise on the outer borders without twisting the legs or bending the knees.

In this exercise the movement takes place entirely below the astragalus; it calls the adductors of the foot only into play.

2. Walking on the outer borders of the feet: with the feet parallel, rise on the outer borders and walk in this position.

This has the same action as Exercise 1, provided the legs are not twisted outward; if one toes in or twists the legs outward, the rotators of the hip are called into play.

3. Rotating the legs outward: stand with feet parallel, or slightly toed in, and twist the legs outward from the hip, keeping the kness straight and the great toe in contact with the ground.

This is a pure hip motion, the leg rotating outward at the

hip and ankle with the foot remaining fixed; it calls into play the outward rotators of the hip; its action in correcting pronation and throwing the weight on the stronger outer portion of the foot is striking. This exercise will be frequently found difficult to learn by persons with weak feet.

4. The ball of the foot is placed on the sharp edge of a depression in the ground with the toes projecting over the edge. A thick board, table, or other secure support may be used. The toes are deliberately bent downward as far as possible. If the toes do not bend readily, assist them with the hands until they become more flexible.

5. The foot is moved backward to a flat surface and the toes are lifted.

6. In the same position the toes are separated and closed. At first it may be necessary to assist this movement with the hands.

These three develop the intrinsic muscles of the foot and raise the anterior arch.

As ordinarily performed, the exercise of rising on the toes is of little value and may even be productive of harm in the case of very weak feet. If done at all, one should rise as high as possible on the toes, separating the ankles slightly while rising. Rising to the extreme degree calls into full use the muscles of the forefoot and deepens the arch (bowstring action of the muscles); separating the ankles in rising affects the adductors of the foot and to a lesser degree the outward rotators of the hip. As this exercise, if properly done, requires a considerable degree of strength, it should not be used at first, and not at all in the case of very weak feet.

In some instances it will be found advisable to raise the inside of the heel an eighth of an inch or more; as the foot grows stronger this may be made thinner or removed altogether. Also in cases of discomfort in the forefoot due to anterior arch weakness or toe affections, the temporary use of

a cleat, an eighth inch or more thick and about an inch wide, fastened to the sole just back of the heads of the metatarsal bones may be of advantage. Anything in the nature of an arch support, however, is naturally contra-indicated for use in active service.

(*c*) *Milder defects susceptible of correction by mechanical or relatively simple surgical measures.*

Owing to the strict rules for disqualification laid down in the General Orders, it is probable that abnormalities requiring surgical attention will be only rarely encountered among tbe present recruits. Those likely to occur will be discussed later.

CHAPTER III.

THE DISABILITIES OF THE SOLDIER'S FOOT AND THEIR TREATMENT.

ACUTE FOOT-STRAIN.

WHEN a muscle is daily called upon to perform a greater amount of work than that to which it is accustomed, and the rest period is not sufficient in that individual for recovery, a condition of chronic local muscle fatigue results. As the muscle is then unable to do the work required of it the stress of use is thrown upon the ligaments, and this results in the production of pain. In the soldier's foot this state of affairs may be brought about by what is for him an excess of load, an excess of use, or use in an improper manner. In consequence we may now have to deal with a condition of very severe pain which may come on very quickly, and which is spoken of as "acute foot-strain." It may be associated with a visibly incorrect foot posture, but it is sometimes seen in persons whose feet are of normal appearance (for the reason that the ligaments have not yet become stretched). The occurrence of this affection may in the individual case be furthered by abnormal general conditions such as incomplete recovery from general acute infections. Should there be considerable local swelling, the existence of an infectious element should be suspected and sought for.

TREATMENT OF ACUTE FOOT-STRAIN.—For the most part, cases which should thus be spoken of suffer so greatly that recumbency is imperative; it is advisable, however, for all

cases which properly come under this heading. Moist compresses, applied continuously, relieve pain and tenderness, and should be used for the first forty-eight hours or until this has been accomplished. Gentle massage, once or twice daily, is of advantage. When the tenderness has perceptibly lessened the foot may be strapped with adhesive plaster in the following manner so as to relax the strained ligaments, the position being that of adduction and supination.

DIRECTIONS FOR STRAPPING THE STRAINED FOOT (FREIBERG).—*Purpose.*—The object of strapping the strained foot is to hold it in such a position that those ligaments which are strained and which have been giving trouble on this account are held relaxed; if the foot is at the same time kept at rest, as in recumbency, it is possible to maintain this relaxation by the adhesive dressing. If the foot is used to bear the body weight, this can scarcely be done in the strict sense of the word; it is possible, however, even under use of the foot, to relieve the ligaments of the stress of weight-bearing to such a degree by means of this dressing that the patient is not only kept free from pain, but the irritation and tenderness at the insertions of the ligaments diminish appreciably. What is essential to the correct application of this dressing is that one have an understanding of the mechanics of the condition for which it is applied, and that each strip of adhesive plaster be applied under tension enough and in such position that it has a real mechanical effect. Thus in the usual case of strained foot, those ligaments are to be relaxed which are strained when the foot acts in its position of functional weakness; since this is abduction and pronation, the foot must be strapped in such a way that it is held in adduction and supination. It is furthermore important that the foot be strapped more firmly than is apparently necessary in order that allowance be made for the slipping on the skin which always takes place, but particularly when the foot is used to walk or stand.

FIG. 5.—Strapping of the foot. Application of the first strip, seen from the outer side.

FIG. 6.—Application of the first strip, seen from the inner side.

FIG. 7.—Application of the second strip, seen from the outer side.

FIG. 8.—Application of the second strip, seen from the inner side.

FIG. 9.—Completed dressing, seen from the outer side.

FIG. 10.—Completed dressing, seen from the inner side.

Sprained ankle might be said to represent this same condition in acute form; the damage to the ligaments being, of course, much more severe. The same principles should guide in the application of the adhesive dressing in this condition; it must be determined which structures are damaged, and the dressing must be applied so as to relax them and maintain apposition of the torn tissues so far as possible.

Materials.—These are required for the typical dressing: six strips of adhesive plaster; three are eighteen inches long and one inch wide and three are ten to twelve inches long and one inch wide, depending upon the size of the foot. These strips should be prepared beforehand and held ready. It is desirable also to include a pad of felt about one-half inch thick, two inches long, and one and one-half inches wide; this is so placed on the lower and inner side of the foot as to support the longitudinal arch.

Application.—The foot is best held by a third person, but not necessarily so; it should be maintained at right angles to the leg and decidedly supinated and adducted. A long strip of plaster is first applied along the posterior border of the fibula, beginning three inches above the tip of the external malleolus. It is made to adhere, pulled taut, and passed across the sole of the foot to the internal malleolus; in so doing the felt pad is placed against the arch of the foot and held by the plaster. Being constantly held taut the strip is now passed upward and slightly outward and made to adhere for the rest of its length over the front of the tibia. A short strip is now taken and its end made to adhere to the external (fibular) side of the foot, beginning over the cuboid bone, close to the border of the sole. Being held taut it should be passed *horizontally around the back of the heel* and along the inner border of the foot. It should cross the first strip at right angles, just below the tip of the internal malleolus. As it reaches the proximal end of the

first metatarsal bone it is brought upon the dorsum so as to end just behind the great toe-joint. In passing this strip it should be pulled upon sufficiently to visibly adduct the foot at the mediotarsal joint. The second and third long and short strips are now applied so as to overlap the others by one-half. The endings of the long strips are made to diverge on the front of the leg like the leaves of a fan.

To complete the dressing and secure the adhesion of the plaster, it is well to apply a bandage, passing this also in such a direction as to secure the desired position of the foot.

NOTE.—In sprain of the ankle, it is most common to see the external lateral ligament bear the brunt of the injury; when this is the case, it is necessary to pass the adhesive straps in a direction just the reverse of that above described. That is to say: the long strap should begin over the lower third of the tibia and should be passed across the sole, over the external malleolus and lower part of the fibula and end on the antero-internal aspect of the leg. The short strap should begin on the inner side of the foot over the scaphoid and passing horizontally around the heel should end on the dorsum of the foot over the fifth metatarsal just back of the little toe-joint.

Further Treatment.—Recumbency should be continued with this dressing in place for a period varying from five to ten days additional. As an alternative, the strapping may be deferred until the patient is ready to walk, in order to permit the use of contrast baths and massage, and the foot may be held in the inverted position by an elastic bandage made from flannelette cut on the bias. After ten days or two weeks, whichever of these two methods has been followed, the measures mentioned under the "alternative" are begun (or continued), together with the use of graduated exercises of the adducting, supinating, and toe-flexing muscles of the foot. Should this not be feasible, or in case the tenderness has rapidly subsided, the foot may be carefully strapped

and walking cautiously permitted for short periods, the shoes having first been properly altered.

The alteration of the shoe is accomplished by having the inner side of the heel raised not less than one-quarter of an inch by the insertion of leather wedges between the lifts; the inner side of the heel should also be lengthened by extending it forward from one-half to one inch, according to the length of the foot. Sometimes the inner side of the sole may be raised as well by applying a wedge of leather with its base one-eighth to three-sixteenths inch thick, just under the great toe-joint. The shoe having been altered, the patient should be instructed not to walk without it, even for a few steps, until the foot has completely regained its strength.

With the resumption of walking it is very important that the patient should be taught to walk with feet parallel and to use the toes in walking. Exercises for restoring the strength of the foot and leg muscles should be taught and insisted upon. (See Chapter II.) Complete recovery may require six to eight weeks. Time is lost by the attempts to use the foot unprotected until the tenderness has been absent for some time.

ORDINARY FOOT-STRAIN.

Foot-strain, as it is ordinarily observed, and apart from the acute variety which has been discussed above, is quite commonly spoken of as "flat-foot," regardless of the appearance of the arches themselves. As the cases present themselves, this whole group of disabilities may be advantageously divided as follows:

1. Flaccid feet.
2. Rigid feet.
3. Spastic feet.

1. Foot-strain in the Flaccid Type.—The condition here to be discussed virtually represents the same mechanism as that represented under Acute Foot-strain, excepting that the symptoms come on in a manner and with degrees of intensity varying from what might be called subacute to chronic. The most striking clinical characteristic is pain in the feet—pain which in cases uncomplicated by infection or external trauma is definitely dependent upon use of the feet, both as regards its intensity and the fact that it begins with the assumption of the erect position in the morning and ends with the evening rest. There is this exception to be made, however, that during rest the feet usually become stiffened and the first moments of weight-bearing are apt to be the most painful of the whole day. This initial great painfulness passes away with the first movements of the day, and the pain which is later experienced is likely to be in proportion to the amount of work which the feet are called upon to do. The pain is located, as a rule, rather indefinitely in the region of the instep and secondarily in the legs, knees, hips, and not seldom in the lower spine. These symptoms are also often combined with those of strain in the anterior arch which are discussed below.

In the examination of the foot, points of tenderness are to be found in accordance with the description found in Chapter I, and which need not be here repeated. Of great importance, moreover, is the determination of the flexibility of the foot and the freedom of its movement (refer again to Chapter I). The diagnosis is established by finding that complete flexibility and freedom of motion are present, and that the pain bears the definite relation to use which is spoken of above.

Treatment.—The treatment of this condition should conform with the directions given for the later stages of acute foot-strain. In some cases the feet will be so sensitive as to make complete rest for a few days advisable. *The use of supports, worn within the shoe and such as are often to be*

recommended in civil life, is incompatible with active military field service. There are some cases, however, in which the use of such supports seems indispensable and in which service for light duty can be utilized until the time has arrived for discarding the supports; for it is to be accepted that such supports are intended for temporary use only; the feet are to be strengthened by correct walking posture, by exercise and contrast baths until the further use of supports becomes unnecessary and therefore inadvisable. The man is not to be permitted to return to full duty until this time has arrived.

2. FOOT-STRAIN IN THE RIGID TYPE.—When the examination of the painful foot as above described reveals the presence of limited mobility, especially as regards supination and adduction, we are dealing with arthritic changes such as adhesions and peri-articular infiltrations, which result in the production of rigidity. This rigidity may be present in greatly varying degree. It may be attributed to the existence of infections either in the foot or elsewhere in the body, or it may be the consequence of trauma, either directly to the foot, as in severe sprain, or contusion, or following severe injuries to the extremity, such as fractures and gunshot wounds.

It is of diagnostic importance to remember that tuberculosis of the joints of the tarsus may closely resemble this type of foot because of the presence of muscle spasm and because the tuberculous foot often has a flattened appearance. The differentiation is sometimes not easy; there is usually distinct muscular atrophy in the affected limb, and the occurrence of painful foot rigidity in one foot only should excite suspicion, even though this happens not infrequently in simple foot-strain of the rigid type. An x-ray examination should be had in any case of doubt.

Treatment.—Fundamentally the treatment of this type of foot disability consists in converting the rigid type into the

flaccid type; after this the treatment of the flaccid type is in accordance with principles already laid down. In cases in which the rigidity is incomplete and not of long standing it will often be possible to dispose of it by carefully strapping the foot, raising the inner side of the heel and sole, and greatly restricting the use of the foot in standing and walking. The strapping should be renewed frequently enough to keep it mechanically efficient and the foot should be examined daily in order to control this. Walking with the foot unshod should, during this period, be strictly forbidden. Should it become evident in the course of a reasonable period, say two weeks, that flexibility is being definitely restored, the strapping may be discontinued; the feet should daily be subjected to careful, complete, but not violent manipulation at the hands of the surgeon, following treatment by baking and massage. Active foot and toe exercises should not be used until rigidity has entirely disappeared; the foot may then be regarded as of the flaccid type.

In many cases the rigidity may not thus be completely got rid of; in cases of very great rigidity it should not be attempted. Recourse, for these, should be had to forcible manipulation under deep general anesthesia; restoration of complete mobility should be here considered indispensable, and following it the foot should be encased in a well-padded plaster dressing with the foot held thoroughly overcorrected; this means supinated, adducted, and at right angles to the leg. In order to produce the last-named position it may be necessary to do tenotomy of the tendo Achillis; the right-angled position must, however, be accomplished in order to ensure success. The plaster dressing should be worn from four to six weeks, depending upon the degree of rigidity. During this period the patient may walk upon his encased feet, the plaster having been made heavy enough to permit this. Crutches should be used during this time. When the plaster is removed the foot should be thoroughly flexible

and the treatment should be continued as described for the flaccid type. Should any rigidity remain after the plaster has been removed the question of military disability arises and should be determined in accordance with the principles laid down in Chapter I.

3. Foot-strain in the Spastic Type.—In a certain number of cases the examination of painful feet discloses the fact that there is limitation of movement, produced not simply by such change about the tarsal joints as are above referred to, but in which there is distinct spasm of the peroneal group of muscles. This is called forth when the attempt is made to supinate the foot, be it ever so gently done; most often it may be observed when the patient is standing, but in either case the tendon of the peroneus brevis and longus stand forth as a hard cord on the fibular side of the leg. The amount of spasm stands in no certain relationship to the degree of other physical abnormality to be seen in the feet, except as it determines the extent to which motion is limited in supination. The symptoms differ in no important regard from those of the rigid type just described, except that there is likely to be tenderness over the tip of the external malleolus and just below it, and likewise of the palpable parts of the peroneal tendons.

Once the character of this type of foot-strain has become evident it must be recognized that successful treatment here also demands its conversion into the flaccid type. This is, however, to be accomplished in all but the mildest degrees of spasm, only by tenotomy of the peronei or even the excision of about three-quarters inch of the peroneus brevis and longus at a point one and a half inches above the malleolus. According to Col. Sir Robert Jones, to whom is due the credit of having first described this condition accurately, the excision of a portion of the tendon should always be done. After the operation the foot should be held, by plaster of Paris, in the position of supination and adduction for three or four weeks,

and after this time it should be handled as before described for the flaccid type.

OSSEOUS FLAT-FOOT.—As another aspect of the rigid type of feet which are giving trouble there should be mentioned the "osseous flat-foot," in which the foot is fixed in its abnormal posture by bony changes. In such case the foot has usually been deformed for years, but it is often capable of heavy work for long periods without causing trouble. Should this condition be encountered in a soldier and its nature be established beyond doubt, it should be regarded as disqualifying for military service in the field.

AFFECTIONS OF THE ANTERIOR ARCH.

Flattening of the transverse arch of the foot results in disabilities of two kinds:

THE FORMATION OF CALLOSITIES ON THE SOLE OF THE FOOT OVER THE METATARSAL HEADS, WHICH MAY BECOME VERY PAINFUL.—The most frequent situation is over the head of the second metatarsal. In marked claw-feet, owing to the presence of contractures of the toes in dorsal flexion, callosities may be present over the heads of all of the metatarsal bones and give rise to great disability.

METATARSALGIA.—This name has been given to an affection marked by attacks of pain, sharp or burning in character, often of paroxysmal occurrence, and which are usually located in the fourth metatarsophalangeal joint, but occasionally in the second or third. This condition is generally attributed to flattening of the transverse arch of the foot through which the heads of the metatarsal bones fall into abnormal relations to one another; when pressed together by the shoe, mechanical irritation results.

Treatment.—Since the cause of these two conditions is the same, and since they are often found associated, their treatment is identical. Relief of the symptoms is obtained by

mechanical support of the depressed arch. For temporary relief, and especially when pain is acute, resort may be had with advantage to straps of adhesive plaster applied transversely just back of the metatarsal heads, especially in combination with properly shaped felt pads. In civil life some form of support is usually placed inside of the shoe, but in military service a cleat of leather one-fourth inch thick and one inch wide, fastened to the sole of the shoe just back of the metatarsal heads, has been found to be the most feasible means of relief. Restoration of function is to be obtained by the use of the toe exercises described under Prophylaxis.

AFFECTIONS OF THE REGION OF THE HEEL.

INVOLVING THE TENDO ACHILLIS.—These are tenosynovitis, bursitis, and periostitis at the insertion of the tendon into the os calcis. Their cause is mechanical, being usually due to strain or to pressure from shoes or leggings. It is associated in some cases with an infectious element, which is often gonorrheal in nature. In tenosynovitis there is swelling and tenderness extending upward along the tendon; in bursitis, tenderness, swelling, and sometimes fluctuation are located over the bursa which is situated just in front of the lower end of the tendo Achillis; in periostitis there is usually not much swelling, but the tenderness is found at the insertion of the tendo Achillis into the os calcis, and may involve the surrounding bone to a greater or less extent.

Treatment.—The treatment consists: (1) In removing harmful pressure or friction, if these have been factors. This may be done by the proper disposition of pads of felt or cotton strapped to the leg just above the point of irritation when the tendon is affected and just below when the bursa or tendon insertion is involved. (2) In relieving strain on the tendon by raising the heel of the shoe one-half to one inch. (3) Occasionally the symptoms are so acute that absolute

rest for a few days will be necessary. In these cases, hot, moist compresses, simple or medicated, are of value, and massage of the neighborhood, avoiding the tender area itself, is very useful. (4) In cases which have become more or less chronic, puncture of the bursa or the inflamed area of periosteum with the hot needle, as recommended by Jones, may be used. Complete disappearance of the symptoms is sometimes slow in taking place and the treatment should not be relaxed until this has happened, otherwise recrudescence will occur. Cases associated with infection are particularly stubborn and of course require attention to the original focus.

Involving the Os Calcis.—These are usually due to periostitis with or without the formation of exostoses (spurs). The common cause is trauma, associated or not with infection. The infection is very frequently gonorrheal; sometimes it follows tonsillar infections. Any part of the surface of the os calcis may be involved, but the most common situation is on the lower surface at the attachment of the plantar fascia. The symptoms are pain on use of the foot and local tenderness. Spur formation most often occurs at the point of attachment of the plantar fascia. It is not to be regarded as necessarily the cause of the pain, which is, instead, usually due to the inflammatory condition.

Treatment.—The treatment of mild cases consists in the use of a felt pad strapped to the sole of the foot in front of the tender area. Diligent search must be made for possible sources of infection in order that they may receive appropriate attention. Usually it will be necessary to take the patient off his feet entirely and use the same measures as are advocated above for acute affections of the tendo Achillis. Since experience has shown that spurs may exist without symptoms, their presence is not to be considered an indication for operation. When their removal is indicated, this had best be done through a horseshoe-shaped incision with

its convexity just in front of the bearing surface of the heel. A flap should be made, including all of the tissues down to the plantar fascia, and should be dissected backward to just beyond the insertion of the fascia. The fascia should be incised longitudinally so as not to disturb too greatly its attachment. A very free exposure of the spur is thus obtained and the scar is so placed as to give no later trouble. The incision from the side, which is often used, gives a much less satisfactory exposure.

HALLUX VALGUS.

Deflection of the great toe toward the outer side of the foot may occur alone, but is usually associated with a greater or less enlargement on the lateral aspect of the joint (*bunion*), and this enlargement may be of the bursa alone, of the bone alone (exostosis) from periosteal thickening, or from both causes in combination; in all cases of hallux valgus, except those of slight degree, the transverse arch is usually flattened to a proportionate extent.

It will be recalled that "hallux valgus, *per se*, is not disqualifying, unless excessive and accompanied by symptoms," and that "bunion, if slight, is not disqualifying, but if large, inflamed, and associated with marked hallux valgus or rigidus is a cause for rejection." Hence, for the early part of the war, at least, cases requiring operative treatment will be rarely, if at all, encountered. Further, it will be realized that while a perfectly serviceable marching foot can be secured by a proper operation, yet the performance of any operation upon the foot may be urged by those so disposed as a reason for discharge for disability.

TREATMENT OF HALLUX VALGUS AND BUNION.—*Palliative.*—Mild cases of hallux valgus will be gradually improved by the use of the army shoe. In cases of temporary irritation of the great toe-joint the conventional bunion ring should be avoided, as it tends to still further deflect the great toe;

half the ring may, however, be used just back of the point of irritation, or a thin pad of felt or cotton may be strapped on with adhesive plaster, thus leaving the great toe free. The fit of the shoe should be verified, and the possible presence of wrinkles in the lining determined; if the shoe is satisfactory in other respects, it may be stretched slightly opposite the point of irritation.

Operation.—Bunion sometimes becomes infected (infectious bursitis). It should then be excised, the wound left open, and treated according to approved surgical principles.

For cases of hallux valgus requiring operation, several procedures are available. The *incision* generally used is a curved one with its convexity either just below or just above the joint, as preferred. The skin and superficial fascia are dissected back, exposing the inner half of the joint. The bursa is removed if sufficiently affected to require it, otherwise it is left. The incision through the capsule is best made so as not to coincide with that through the skin; if the interposition of a flap should be thought desirable, a curved incision is made as far as possible anteriorly and with its convexity toward the toe, and the flap is prepared so as to include both capsule and bursa. The inner half of the metatarsal head now having been fully exposed *the enlarged inner portion of the head is removed* with the chisel; this should include both bone and periosteum, and must be carefully done so as to leave a perfectly smooth inner surface, the slightest unevenness causing possible trouble later. If the difficulty has been chiefly from the bunion, without much deflection of the toe, removal of the enlargement will alone prove sufficient and the incision may now be closed. If, however, deflection of the toe is sufficient to require attention, one of the following methods is now used:

(*a*) A wedge-shaped portion of the metatarsal head with its base toward the inner side is removed and the end rounded off smoothly, with or without the interposition of the flap

previously mentioned. It is essential that enough of the head be left to allow sufficient bearing surface, otherwise the strength of the foot will be impaired.

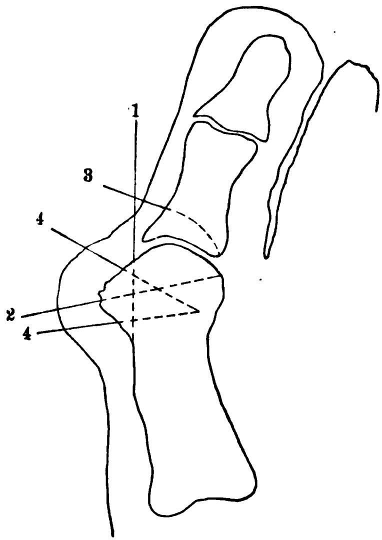

FIG. 11.—Illustrating lines of bone division in the various operations. 1, removal of bony enlargement; 2, removal of wedge-shaped portion of metatarsal head; 3, removal of wedge from phalanx; 4, wedge-shaped osteotomy back of metatarsal head.

(*b*) An extremely satisfactory procedure, which obviates the danger of impaired support and apparently permits of earlier use of the foot in walking, consists in removing a wedge-shaped piece from the proximal end of the phalanx, which is then given the proper concavity, required for articulation, with a curved chisel. No flap is required.

(*c*) Wedge-shaped osteotomy just back of the metatarsal head is also used to correct the deflection.

If the flap is used to cover the rough end of the metatarsal bone (method *a*) it must be fastened in place by catgut sutures, one to each corner of the flap; these are passed with a straight needle from the inside of the joint out through the skin at the *upper* and *lower* outer aspects of the joint and are tied under moderate tension only.

The capsule is sutured with catgut and the skin closed with catgut, horsehair, or fine wire. A gauze pad is placed between the first and second toe, or a splint may be used to hold the great toe in hallux varus and the usual dressing applied. Weight-bearing, except on the heel in case of need, is not usually advisable for two weeks. A proper shoe should be worn as soon as possible, even before walking is permitted, to overcome swelling. A shoe which has become distorted from use before operation was done, should under no circumstances be worn afterward. After about the tenth day following operation, the patient should be instructed to move the great toe joint daily, in all directions. After about two weeks the patient should be instructed to carry out exercises for flexion of the toes as described under Prophylaxis.

HALLUX RIGIDUS.

This is a condition in which there is limitation of the range of motion in the first metatarsophalangeal joint; it most commonly involves dorsal flexion. In the absence of acute symptoms the affection is marked by enlargement around the joint (or at one point only) and limitation of motion; both of these are usually due to new bone production around the margin of the joint. When the joint has been irritated by what for it is overuse, acute symptoms appear—more or less congestion, swelling, and pain on forced movement. Palliative treatment may be employed in very slight

cases, and consists in applying a cleat of leather, three-sixteenths inch to one-quarter inch thick and one inch wide, to the sole of the shoe just back of the heads of the metatarsal bones, with measures to allay the acute symptoms when present. Operative treatment is called for in cases which cannot be so relieved and consists of the removal of the exostosis or a portion of the head of the bone as outlined above.

HAMMER-TOE.

This is a deformity, usually of the second toe, consisting of a contracture in dorsal flexion at the metatarsophalangeal joint accompanied by contracture in plantar flexion at the proximal interphalangeal joint. It becomes disabling when the feet are called upon for heavy service by rubbing of the prominent plantar flexed knuckle against the top of the shoe and the thrust of the end of the toe against the sole; painful corns are the result of this.

TREATMENT.—The common practice of amputating such toes is to be condemned for the reason that the loss of any toe results in a weakening of the foot. The operation to be preferred consists of a wedge-shaped excision of the interphalangeal joint with the base of the wedge upward, together with tenotomy of the extensor tendon just back of the metatarsophalangeal joint. In very severe cases it is advisable to transplant the proximal end of the extensor tendon into the shaft of the metatarsal bone close to its head, instead of doing a simple tenotomy. After the operation a small plantar splint is applied and is to be worn until ankylosis is complete.

DEFORMITY OF LITTLE TOE.

Deformities of the little toe occur in a manner similar to those of hallux valgus and hammer-toe, and should be treated on the same principles.

TRENCH FOOT.

"Trench foot," which was very common among the troops in Northern France during the first year of the war, is the generally accepted name for a condition in which the changes resemble those seen in frost-bite.

It is caused by prolonged exposure to low temperature and moisture, acting together, and is favored by restricted circulation (as induced by pressure from boots and puttees or leggings) and by the lowering of the general circulation.

The affection is markedly similar to Raynaud's disease; the two varieties, the blue congested and the white, being exactly reproduced; the former, however, markedly predominating. It is apparently the results of a vasomotor constriction which passes on to "paralysis, with damage of the capillary walls and consequent hemostasis, exudation and finally gangrene." The anesthesia is to be regarded as the result of the neuritis.

The onset of "trench foot" is insidious: the first thing noticed is the increasing coldness of the feet, with final entire loss of feeling. Except for the discomfort associated with the cold feet, pain is not complained of at first; later, as the feet begin to swell, pain appears usually around the ankles and extends at times into the calves, that is, it is confined to the parts where the circulation, while impeded, was not stopped; as the circulation begins to be restored, pain becomes the chief complaint and persists long after the foot has become warm to the touch and of healthy appearance; the pain is neuritic in character and apparently very severe, especially at night.

Mild cases present: (1) extreme coldness; (2) a light, pinkish blush over the toes and ball of the great toe; (3) slight swelling, or, if seen late, its former presence may be evidenced by some wrinkling of the skin; (4) blurred sensation; (5) pain on pressure; the more severe cases are marked

by (6) massive edema, (7) cyanosis, (8) bleb formation, (9) severe organic change; the most severe develop (10) gangrene.

Valuable *diagnostic points*, particularly in detecting malingering, are the nocturnal character of the pain and its increase by warmth.

As to *prognosis*, mild cases should be fit for duty in about three weeks; those with edema usually require about three months. Even after apparent cure an increased vulnerability to cold is present.

Treatment.—Treatment is divided into (*a*) treatment of the attack, and (*b*) the use of preventive measures.

Treatment of the Attack.—Elevation of the feet with exposure to the air and heliotherapy or, when this is not available, to electric-light baths are the only measures indicated in severe cases. Massage should be begun when the edema lessens and should be given preferably twice daily. Warm foot baths may be given daily in mild cases. Tapping of the bullæ, when present is indicated. Various applications are used as indicated. Morphin is the only drug that relieves the pain. High-frequency electricity has been tried with promising results. If any abrasions are present, a dose of antitetanic serum is given.

Preventive Measures.—(*a*) Trenches must be kept as dry as possible.

(*b*) Precautions in the care of the feet before entering the trenches are required: rubber boots have been found of the most value; whether boots or shoes are worn they must be roomy, and both foot and leg coverings should be laced or fastened loosely; the oiling of the feet with whale oil, a thin film only being applied, is apparently of definite value, but is objected to by the men, as the smell of the oil is unpleasant, and, if abrasions are present, they are likely to become infected.

(*c*) Proper care of the feet while in the trenches must be taken: shoes must be removed daily, the feet well rubbed

and greased, and dry socks put on; it is a help if it can be arranged so that at this time the man can lie down (on tarpaulin) and do overhead exercises with his feet; boots or shoes must be properly dried, preferably on a rack which permits them to be so placed that the moisture will settle in the back of the heel, where it can be readily sopped up; the men should also be encouraged to stamp their feet and move their toes inside their shoes frequently.

(*d*) Warm food should be served to the men while in the trenches, and, if possible, twice a day.

CHAPTER IV.

INJURIES TO JOINTS AND THEIR TREATMENT.[1]

GENERAL OUTLINE OF PRINCIPLES.

THE fundamental principles of treatment depend on a recognition of the fact that the function of a joint is mechanical, that the processes of repair follow the ordinary physiological laws, and that mechanical injury of the area of repair will retard a cure and often give rise to a state of subacute or chronic inflammation, which may confuse the issue, unless the surgeon clearly understands the condition with which he has to deal. Strain of the inferior calcaneo-scaphoid ligament is an example which should be familiar. After a few days' rest the foot is free from pain, but the first route march brings a return of the trouble, which might have been permanently relieved by a small alteration of the heel of the boot to divert the body weight on to the outer side of the foot, and so save the injured ligament from unnecessary strain until it has fully recovered its strength.

It will therefore be necessary to deal not only with injuries of the joints themselves, but also with those of structures about joints, in order that a clear diagnosis may be made.

The two chief difficulties which seem to trouble most practitioners who have not had the opportunity of handling a large number of joint injuries, are to decide what is the

[1] This chapter, except the section on Treatment, is taken from "Injuries to Joints," by Col. Sir Robert Jones.

most appropriate immediate treatment, and when and how to commence moving the injured joint, especially after the more serious injuries.

The solution of the first is found in accurate diagnosis of the injury, and in forming a clear idea of the mechanical and physiological factors which enter into the processes of repair. As a simple illustration of this we will assume that a man jumping from a wall or into a trench lands on the edge of a clod of earth, and violently twists his foot inward. He feels a sharp stab of pain on the outer side of the ankle, his neighbors perhaps hear a sharp click which makes them think he has broken a bone. By the time the man has limped about and is seen by a surgeon, the whole ankle is swollen and painful. Having excluded a Pott's fracture by running his finger down the fibula and finding it intact, the surgeon makes the diagnosis of "sprained ankle." The time-honored remedy of cold-water bandages or the application of some cooling lotion combined with rest "until the swelling goes down" is in many cases too frequently adopted; the patient subsequently being allowed up in a soft slipper, which is almost the worst thing he can do in the convalescent stage. Although the ankle is very painful, it will bear gentle but firm handling; the history points to an injury about the external malleolus, and the inference is that there is a rupture of one of the three slips of the external lateral ligament of the ankle, or perhaps an avulsion of a scale of bone from the tip of the malleolus, which is technically a fracture, but for all practical purposes a sprain. Pressure with a finger over each division of the external lateral ligament in turn will find a point of extreme tenderness, and so we locate exactly the injury.

The treatment carried out should be with the definite object of getting the torn ends of the ruptured ligament to unite by first intention, or to avoid confusion with the terms first and second intention as commonly applied to

the history of aseptic and septic wounds, let us say by *immediate* rather than by *delayed* union.

First, the foot should be pronated in order to relax the ruptured ligament and bring the torn ends as near each other as possible. Second, avoiding for the present the question of massage, the effusion can be got rid of by firm bandaging over several layers of cotton-wool, the bandages passing not in the orthodox manner from within outward across the front of the leg, but from *without inward* so as to keep the foot everted. Third, a rectangular foot-splint should be applied to prevent any recurrence of the ligamentous strain.

The boot—a comfortable one—should have a couple of wedge-shaped patches of leather put on the heel, base to the outer side, to maintain pronation of the ankle when the patient stands. According to the promptness with which treatment is commenced, all swelling will have disappeared in from twelve to thirty-six hours, with the exception, perhaps, of a little local swelling around the seat of injury.

It may be advisable in some cases to apply a pad of sticking plaster, sticky side outward, to fit over the area of injury. This pad should be about three-quarters of an inch wide and half a dozen layers thick; the foot can then be strapped in the pronated position, the strapping being applied as a figure-of-eight bandage. This makes an excellent local splint. The united effects of the strapping and the wedge heel make it impossible for him to put tension on the torn ligament when walking. The physiological exercise of the foot will prove a better stimulus to the normal processes of circulation and repair than even the best massage. Provided no strain is allowed at the seat of the injury, in a few days the foot will give no further trouble, in a fortnight he may be fit for full duty, even after a bad sprain. If instead of a boot, he wears a shoe, or still worse, a soft slipper, he is sure to tear the young cicatricial tissue forming between the ends of the torn ligaments, which can then only recover

by *delayed* union. Everybody knows that a sprained ankle may make a man lame for many weeks, but the period of incapacity depends largely on the mechanical efficiency of the treatment he receives as well as on the severity of the original lesion.

A rough classification of the injuries of which we propose to treat may be given as follows:

1. Strains of Muscular Attachments.—Strains of muscular attachments about joints often give rise to serious impairment of function. From incomplete diagnosis these conditions are often inefficiently treated. They are diagnosed by the fact that there are certain movements which the patient cannot perform because he is suddenly pulled up by pain, which he localizes fairly exactly at some point about a joint. Careful testing of the movement which hurts will generally prove that active contraction against resistance, or passive stretching of a certain group of muscles, causes the pain. Further careful palpation will find a tender spot just at the attachment of a tendon, over an area perhaps no bigger than a dime, and a little swelling with a suggestion of edema or fluid may be felt deep down on the surface of the bone. This tender spot is the key to the situation. It is a small patch of effusion below the periosteum or in the fibers of the tendon which run in and through the periosteum to the bone, constituting the origin or insertion of the muscle.

The pain is due to tension on this effusion caused by tension on the muscle or by direct pressure on the edematous spot.

Such an injury may be acute in type, arising from a single sudden wrench, stretching, tearing, or otherwise loosening the strong fibrotendinous plexus; it may be subacute, arising from repeated smaller injuries, as in the familiar "tennis" and "golf" elbows; or either of these may pass on to a chronic stage, never entirely dormant, and liable to become more acute on any provocation, and this chronic stage may con-

tinue for weeks, disabling the patient from taking part in active pursuits. The reason why this trifling injury is often so long continued and troublesome is that every time tension is put on the muscle a fresh assault is inflicted on the injured tissues, and this repeated injury maintains the effusion and prevents repair of the stretched or torn fibrils.

Treatment should therefore be directed definitely, first, toward getting rid of the effusion which separates the torn ends of tissues and so allowing them to come into their proper position; second, toward preventing any movement or muscular effort from stretching and tearing the newly formed repair tissue and so making the condition chronic.

This may be done (*a*) by firm pressure with a folded pad of sticking plaster strapped over the area of effusion to promote its absorption and to act as a local splint on the injured fibers; (*b*) by a similar pad and strap placed on the tendon just above the inflamed area; this acts as a stop, preventing the tension on the muscle from being transmitted in its full force to the injured attachment. This is comparable to the half-turn round a post which a sailor takes with a rope when he wishes to check a movement which he could not stop by the direct application of his strength. This is no new principle, although sadly overlooked by the profession, for every workman who puts a strap round his wrist to ease a strained tendon is putting it into practice. The wonder is that so few surgeons apply it to the deltoid, the quadriceps extensor, the ankle and the foot, as well as to the wrist.

We often have to deal with the chronic case. Here the trouble is that repeated small injuries with repeated efforts at repair have produced a small plexus of new fibrous tissue, which itself impedes the free access of blood necessary for the complete removal of effusion and the conclusion of the processes of repair.

Treatment must then be directed to encouraging a free flow of blood to and through the injured area. This is not

effected by a passive congestion, but by massage and alternate applications of hot and cold water, by counter-irritation, and in obstinate cases, where the pain is confined to a very limited area, by puncture with a heated needle, which both destroys implicated nerve-ends and produces an increased flow of blood.

2. SPRAINS OF LIGAMENTS.—Sprains of ligaments, that is, rupture of fibers of ligaments. This injury may occur anywhere in the extent of the ligament, either at one of its attachments or in the body of the ligament. All the general remarks about the nature of the processes at work made in the previous section apply to these injuries.

First localize the injury accurately, then reduce effusion, and finally prevent repetition of the injury by preventing mechanical strain.

The above two classes of injury should invariably end in recovery without any impairment of movement, the time occupied depending largely on the efficiency of the immediate treatment.

In the more severe types of injury stiffness or ankylosis may arise as a result of efforts at repair. In such cases there must be added to the immediate treatment to secure repair of injured tissues, a carefully considered scheme of after-treatment to restore freedom of movement.

3. EXTENSIVE RUPTURE OF LIGAMENTS, INCLUDING DISLOCATION.—In cases of dislocation, obviously, *reduction* of the *displacement* is the first consideration. Next, the joint must be left at rest to allow repair of the extensively torn soft tissue. This repair means a considerable deposit of new fibrous tissue. Short strong bands of fibrous tissue about a joint which impede freedom of movement are spoken of as "adhesions," and a time may come when it is necessary to break down these adhesions. It is important to know the right time for doing this. It is unfortunate that in many text-books of surgery the phrase "early passive movement"

has been employed without clearly defining the limits of its usefulness. This is not really difficult if due regard is paid to the histological processes of repair. Take, for example, a posterior dislocation of the elbow without any fracture complications. The dislocation has been reduced and the elbow put in an acutely flexed position to relax the torn anterior ligaments. Between and about the torn ends of the ligaments there is a mass of blood clot and plastic effusion, part of which will be absorbed and become organized by the ingrowth of bloodvessels and fibroblasts laying down new strands of white fibrous tissue. If we could see this a few days later, the whole area would be a vascular mass, corresponding to the stage of granulations of a surface wound, and, like the surface wound, tender to finger pressure. This tenderness to pressure is an important index, for it means that the cicatrix is still so fresh and vascular that any attempt at passive extension will tear the new tissue, cause pain, more bleeding, and more effusion, the repair of which means a more dense fibrous cicatrix than is desirable, resulting in unnecessarily strong adhesions.

If the surgeon restrains himself and leaves the movement to the patient, in the case of the elbow, slackening the sling each day so that the wrist falls a little lower, but on no occasion so far as to tear the cicatrix, and allows the patient to flex and extend his elbow within the limits allowed by the sling, *without pain*, then we may expect local tenderness to die away, and a natural recovery to take place.

This process of recovery may be expedited by a judicious exercise of passive movement. The joint should be gently moved through its complete range of movement, and rested until it recovers from the assault. The object is to release the joint from obstructing bands, and this must be done in such a way as to minimize reaction. *Once* and *once only* should it be flexed, extended, pronated, and supinated at each manipulation. This can be repeated each day or at

longer intervals according to the degree of reaction produced. The to-and-fro oft-repeated method must be utterly condemned.

We should never add the injury caused by passive movement to an existing active state of reparative inflammation, but wait until the reparative action has quieted down. If the patient's range of voluntary movement the day after passive movement is less than before, it is a clear indication that the joint is still too actively inflamed to undergo passive movement. If after passive movement the pain is less and the range of movement is greater than before, it is safe to go on with both active and passive movement.

4. Injuries of Joints Associated with Fracture.—Injuries of joints associated with fracture, either into the joint or so near the joint as to affect the proper relation of the joint surface to the line of the limb, and compound injuries including gunshot wounds, which smash bone as well as tear soft parts, introduce new complications, which must be foreseen and so far as possible guarded against by anticipatory treatment. Fragments of bone or masses of new-formed callus may form a mechanical obstruction to movement. A most conspicuous example of this is to be found in the front of the elbow, where a block of bone may obstruct flexion. This danger is obviated by fixing the elbow in the fully flexed position.

In cases of fracture into the joint or bullet wounds which have destroyed the joint cartilages, some degree of repair tissue may be formed between the two bones. If this repair tissue remains fibrous, a good functional joint may be secured by treatment which will be referred to later. If this repair tissue should ossify, absolute ankylosis will result, and may call for operation. When bony ankylosis is foreseen as inevitable, the surgeon must decide in what position the joint is to be allowed to ankylose, so as to obtain the best possible function for the limb.

In the upper limb the use of a knife and fork, the difficulties associated with collar-studs and dressing the hair, and manifold other considerations, help us to decide the question, while in the lower limb we desire a firm support for walking with a minimum of limp.

The question of an operation to form a false joint does not arise in the first instance; it is only to be considered when the result of the original treatment has ended in an intolerable condition, and then the patient must help us to decide.

PAIN AND STIFFNESS IN RELATION TO DIAGNOSIS AND TREATMENT.

Pain and stiffness in and about joints are valuable aids to diagnosis and treatment.

In cases of recent injury about joints, where the whole region of the joint is swollen, the patient very often complains that the whole joint aches, and says that he cannot bear it to be touched.

If the surgeon approaches the case gently he should be able to determine at once whether the injury is a serious one of the joint itself, or merely some less important injury of structure outside the joint.

To do this it is necessary to avoid hurting the patient, because then the muscular resistance excited by the pain will make further accurate examination very difficult. An injured joint resents any sudden jar or jolt, and when there is effusion in the cavity of the joint, any movement of it may raise the tension, and thus cause pain.

The hands should therefore first be laid on the limb above and below the joint very gently. If the history of the injury suggests that it is most likely a rupture of some ligament, the hands can be passed gently over the joint, feeling for some point of acute tenderness over the ruptured ligament.

Next the limb may be held firmly above and below the joint and very gently moved.

Localized Pain.—If it is found that some movements—those which do not put tension on the suspected ligament—do not cause much pain, and are not strongly resisted, while the least movement in the direction which stretches the suspected ligament is immediately resisted and causes sharp pain in the region which was found to be most tender to touch, it will be pretty clear that the injury is located to one structure or group of structures, muscular or ligamentous, on one side of the joint. The surgeon has then a guide to help him to decide in what position he is to place the limb, and he can confirm his diagnosis later when the swelling and first tenderness have passed off.

The diagnosis of severe joint lesions is often obscured by swelling, and, indeed, in many very serious injuries involving bone and ligaments, bony deformity may be entirely masked. The surgeon should at once be put on his guard by the fact that any movement of the joint is at once resisted and causes pain. We therefore get a rule of guidance:

1. Pain on movement in every direction suggests a lesion in the joint or in parts intimately connected with it.

2. Freedom of movement in one or more directions, but not in all, suggests a lesion of some groups of structures outside the joint proper.

Pain Due to Contusion of Joint Cartilage may not make its appearance until two or three weeks after the accident. This condition is not described in text-books. It occurs in a very typical form in the shoulder-joint in association with Colles's fracture of the lower end of the radius. A patient falls heavily on the hand and sustains a Colles's fracture. The fracture is treated, but no complaint is made of the shoulder. A fortnight or three weeks later, when the fracture is getting better, and greater freedom of the limb is allowed, the patient experiences pain when he

tries to move the shoulder. He considers this due to stiffness, and goes on moving his shoulder, and soon both pain and stiffness become worse. The doctor too often tries passive movement, and the shoulder gets still worse. A vague diagnosis of "rheumatism" is often made, and later the patient, failing to obtain relief, does nothing, and in three or more months his shoulder recovers. What has really happened is that at the time when he fell on his hand he bruised or crushed the shoulder-joint cartilage. Cartilage, like the cornea, is a non-vascular structure. When the cornea is injured, no repair can take place until a little leash of new vessels grows in from the nearest part of the sclerotic. When repair is complete, these vessels disappear, leaving a fine hair streak leading from the sclerotic to the nebula, which is the cicatrix at the seat of injury.

Much the same process occurs in an injured joint cartilage. The débris of crushed cells and cartilaginous tissue cannot be cleared away until new vessels have grown in, constituting a process of reparative inflammation. In the injury of the shoulder associated with a Colles's fracture this process starts while the patient has his arm in a sling, and goes on quietly without his knowledge. At the end of a fortnight or so the vascularization of the cartilage is active, and the effect of movement is to rub the inflamed cartilage and add to the preëxisting injury, consequently the result of movement is that there is more pain.

The seat of the inflamed area is within the joint, and movement is limited and resented in every direction.

Rules.—I will formulate certain rules which may be helpful in deciding whether to move a joint or not.

(*a*) A joint may be assumed to be free from arthritis when even one of its movements is free.

(*b*) Traumatic arthritis follows an injury after an interval of free movement lasting usually over a fortnight.

(*c*) Restricted movements due to adhesions are noticed very shortly after the occurrence of injury.

(*d*) Except when following serious injuries, adhesions restrict the movements of joints in one or more, but not in all directions.

(*e*) A joint, the seat of arthritis, should not be moved until all inflammatory symptoms have subsided.

(*f*) If adhesions are broken down under an anesthetic, the joint should be put through its complete range of movement, otherwise a recurrence of symptoms may be expected.

Pain in Cicatrices.—Pain at the site of a healed injury is often very confusing to the practitioner. Very often after an injury due to violence, repair is only accomplished by the formation of a considerable mass of cicatricial tissue. If there has been a suppurative wound associated with much bruising and tearing of the soft parts, as in a shrapnel or bullet wound which has driven shattered bone through the soft parts, there must be for a long time a mass of cicatricial tissue in the deeper parts of the wound, often out of proportion to the size of the surface wound of entry.

After the sepsis has been overcome and the wound has healed, these cicatrized areas remain tender; shooting pains are felt, and are sometimes called neuritis, though there is no real inflammation of nerves; often the pain passes off when the patient uses the limb, but reappears at night; such cicatricial areas are also sensitive to changes of atmospheric pressure. Pain of this type is generally due to irregularities of blood-pressure. If such an area were superficial it would be a dusky scar, obviously the seat of venous congestion, and the treatment would be to promote vascular activity. To test this in deeply situated cicatrices about joints, all that is necessary is to promote a rapid flow of blood to the surface by lightly slapping and massaging the skin. As soon as a rosy flush appears on the skin, ask the patient to move the joint, and if he can do so with less pain and stiffness than

before, it will be obvious that the slight alteration in blood-pressure has made all the difference.

The treatment advised will therefore be:

(*a*) To use the limb with tolerable freedom.

(*b*) To assist the restoration of free circulation by deep massage.

(*c*) To relieve pain at night, by hot applications to the surface, so that the patient may have longer periods of undisturbed sleep.

Electricity, especially high-frequency current and diathermy, and also hot-air baths and radiant heat, relieve pain of this type, but in all cases the venous congestion and pain return as the limb cools down.

As these measures are often not available, a very simple remedy which is always accessible may be substituted, namely: contrast baths (see page 85).

STIFFNESS AND LIMITATION OF MOVEMENT.

Stiffness and limitation of movement may be due to several different causes; and the type, significance, and treatment vary accordingly.

First there is a stiffness or limitation of movement due to muscular resistance which is associated with pain, the result of some inflammatory or traumatic lesion. Such stiffness is a natural physiological phenomenon; it has been referred to already in the discussion on the meaning of pain, and needs no further mention beyond a reminder that limitation of every movement of a joint is an indication of arthritis or of a serious injury of the joint, while limitation of only certain movements indicates only a local lesion, most probably outside the joint.

Next there is stiffness, or limitation of movement which we may call mechanical in origin, due to fibrous adhesions, to blocking of the range of movement by fragments of bone

or deposits of callus, and in the extreme case it may be due to bony ankylosis.

1. Fibrous adhesions about a joint are the result of cicatrix formation after trauma or an inflammatory lesion. Enough has already been said of the danger of increasing the amount of cicatricial tissue by injudicious passive movement too early in the course of repair.

On the other hand, too prolonged fixation gives the newly formed cicatrix time to stiffen, but this is the lesser of the two evils. When the local effusion and tenderness abate, the patient may be allowed to commence gentle active movements. He is not likely to carry these out sufficiently roughly to tear or damage newly formed scar tissue, because pain will act as a check.

On passive movement, a joint with fibrous adhesions conveys a characteristic sensation to the hands of the surgeon, which differs on the one hand from muscular resistance associated with pain, and the abrupt blocking of movement caused by a bony obstruction on the other. The cessation of movement is definite and unmistakable, but it is not associated with pain, unless the surgeon exerts a little force to put tension on the fibrous band. If in any doubt whether there is disease of the osseous elements of the joint, an *x*-ray photograph should be taken, when the clear structure of the bone, smooth and even contours of the joint surfaces, and the absence of blotched or cloudy patches in and about the ends of the bone, will definitely exclude active disease.

On the Breaking Down of Adhesions.—The treatment then is to break down the adhesions under full anesthesia. To relax all muscular resistance gas is not sufficient. It is no use making half-hearted attempts; these only give rise to effusion and increased stiffness. Every resisting band must be stretched or ruptured by steadily continued and increasing tension. Sudden jerking movements must be avoided because (*a*) they are inefficient, (*b*) they cause

unnecessary irritation of the tissues and unnecessary effusion, (*c*) they may break a bone instead of rupturing the fibrous band.

In the case of the shoulder the arm is first abducted, care being taken not to strain the joint by overabduction. An essential rule, especially in old people, is to control the manipulation by a comparison with the sound arm, as considerable variations in the range of movements are to be noted in different individuals. An assistant should fix the scapula and, with his fist in the axilla, put pressure upon the head of the humerus to prevent dislocation. First with the arm lying at the side of the chest, and afterward in the position of abduction, the humerus should be rotated inward and outward. This movement should be performed very slowly and yet very thoroughly. It is the movement most likely to cause fracture near the joint. The last and most frequently neglected movement is that of forcing the elbow back while the arm is fully abducted. During all these movements, the scapula is fixed. It should now be released and allowed to participate in the complete elevation and abduction of the limb, lest it should have formed adhesions separately from those about the joint.

The same principles apply in breaking down adhesions of other joints. In the case of the elbow, if the adhesions are tough, care must be taken not to produce a fracture. In such an instance, it is a good practice to protect the humerus and bones of the forearm by applying splints of sheet metal above and below the elbow. It will then be practically impossible to produce a fracture excepting at the olecranon, which has to be carefully guarded.

The most striking results are often brought about in the case of the knee, if we remember one very important point, and that is, to secure the full rotatory range. If we confine ourselves to ordinary flexion and extension, we miss those cases of adhesions which follow displacements of the semi-

lunar cartilage and injuries to the internal lateral ligament. In breaking down adhesions in the knee to correct the stiffness following fracture of the lower end of the femur, the thigh should be carefully splinted, as the bone may easily be fractured again even after several months.

After adhesions have been broken down, the treatment should consist of massage and both passive and active movements. The passive movements should be carefully regulated, the active should be unlimited. As soon as the patient has sufficiently recovered from the anesthetic, he should be put through all his movements. He will then be convinced of the freedom of the joint and this will prove a valuable asset toward recovery.

Blocking of Movement by Bony Obstructions may be due to many causes, such as:

(*a*) Myositis ossificans traumatica, which is peculiarly associated with dislocations of the elbow, will be dealt with when discussing injuries of the elbow.

(*b*) Fragments of fractured bone, or even a projecting end of bone in an uncomplicated fracture about a joint.

(*c*) Excessive formation of callus near a joint.

(*d*) Unreduced dislocations.

The occurrence of myositis ossificans can neither be foreseen nor prevented, but the other conditions can be foreseen, and ought to be prevented, though in septic compound wounds, such as occur in the present war, failure is sometimes inevitable. It is, however, all the more important to understand the difficulties and the means of meeting them, for it is only in the earlier stages of treatment that the obstruction can be dealt with easily.

Obstruction of movement of a joint by a projecting end of fractured bone occurs most frequently in fractures about the condyles of the humerus. It is the lower end of the upper fragment which usually projects forward. This is entirely due to imperfect reduction of the displaced fragments. It

should be prevented by proper complete reduction in the first instance. If, for any reason, the lower fragment slips back during treatment, it should be again brought forward before the callus is too hard to be forced.

So long as callus is tender on pressure or manipulation, it is safe to say it is not too hard to be twisted or forced by manipulation so as to adjust an erroneous or imperfect reduction.

Passive movement is undesirable in the stage of repair during which the seat of a fracture is still vascular and tender, and not consolidated, and therefore permits of forcible readjustment of the position of the fragments of bone; this corresponds to the tender vascular stage in the cicatrization of soft parts. So, just as tearing the soft cicatrix means more effusion and excessive cicatricial tissue, the necessity forcibly to twist or readjust callus after it has begun to form carries with it the penalty that the increase of exudate may result in excessive formation of bony callus. Small displaced fragments should not be left where they will obstruct the movement of the joint. The ideal treatment is to get them back into their place. A common example where this can be done is found in the fracture of the anterior edge of the lower articular surface of the tibia, which often occurs in association with Pott's fracture of the fibula. All that is here needed is to dorsiflex the foot when setting the fracture; the surgeon then pushes the wedge-shaped piece of bone back into position, where it is held by keeping the foot dorsiflexed.

At the elbow fragments of bone blocking full flexion will usually be pushed aside when putting the joint into full flexion. If the fragment will not get out of the way, there should be no hesitation about readjusting or removing it by operation.

The formation of excessive callus, *i. e.*, excessive osseous formation in the exudates of blood and lymph about the seat of injury, may be determined by the violence of the

original injury, which of course is beyond the surgeon's control, but is often due to unnecessary irritation of exudate at a later stage by imperfect fixation, by allowing injudicious movements, or by unwise attempts at passive movement before the callus is firm enough to withstand them. Everything that has been said about the dangers of too early or too rough passive movement in connection with fibrous cicatrices in soft parts applies much more strongly where the process of repair includes ossification, for fibrous bands can generally be stretched or ruptured if necessary, but osseous formations are not so easily disposed of when once they are fully formed.

It is a physical law that matter occupies space; therefore if no space is left in which excessive callus may form, it cannot be formed. This method of meeting the difficulty can be employed at the elbow, for if the joint is fully flexed during treatment of a smash about the condyles, no excess of callus can form in front to block flexion; behind, the broad tendon of the triceps serves the same purpose. The only exception to this rule of full flexion in elbow injuries is when the olecranon is fractured.

ANKYLOSIS.—Ankylosis may be fibrous or osseous, and is a serious menace to movement. It arises when the cartilaginous surfaces of the joint have been injured, leaving raw surfaces between which repair tissue may be formed.

This repair tissue may only go the length of fibrous tissue; by judicious exercise this may gradually stretch and a reasonably useful joint result. Attempts at violent stretching or rupture of the fibrous tissues connecting the joint surfaces are generally to be regarded as injudicious, because they excite increased exudate which forms a basis for more cicatricial tissue, and also because violent handling may excite the bone cells communicating with the joint through the injured cartilage to activity, and then the osteogenetic cells will invade the area of exudate and produce osseous repair.

Hence, in a case of fracture into a joint, or of a bullet having traversed the joint and ploughed up the osseous cartilages, the line of treatment must be directed toward obtaining healing of the breach of surface on each bone separately, and allowing the union from one to the other to be as slight as possible. When sufficient time has elapsed for repair to have commenced, slight movements should be allowed. These should be such movements as would tend to produce non-union in the fracture of the shaft of a long bone. Part of the treatment of ununited fracture of a long bone is to manipulate the seat of fracture roughly, so as to produce fresh exudation and vascular activity and to excite osteogenetic processes. It is therefore obvious that violent movements of a joint, instead of securing non-union between opposing surfaces, may have the opposite effect.

When bony ankylosis is seen to be inevitable, or is seriously to be feared, the position in which the limb is placed during treatment is of great importance. The guiding factor is the function of the limb.

In the upper limb, usefulness of the hand is of first importance, and treatment is planned accordingly. A limb with an ankylosed joint may still be very useful.

In the lower limb, weight-carrying and locomotion demand stability, and this must guide the surgeon. In injuries about the vertebræ, the object is to preserve the erect attitude, because the spine must carry the weight of head and shoulders. If a hunchback is once formed by yielding at the seat of injury, the weight of head and shoulders will tend to increase the deformity.

Neurotic Stiffness of Joints.—It frequently happens that after some injury which has caused a considerable amount of pain, stiffness of the joint persists long after local repair is complete, without any mechanical cause being apparent.

These cases are among the so-called cases of neurotic or hysterical joints. They really depend on a persistence of the

habit of keeping the joint still which was acquired during the stage of acute painfulness. The fault is often in the patient, sometimes the surgeon must share the blame. An instance of the latter state of affairs came under the author's notice about two years ago. A boy injured his knee: the doctor very properly fixed it on a straight splint until all pain and swelling had disappeared. He so strongly impressed on the mind of the boy and his mother that he must not move the knee or he might have a relapse, that more than a year later the boy appeared in hospital suffering from a "stiff" knee.

Practical demonstration that the knee was not really stiff by moving it through a small angle greater than the boy had accomplished since his accident, and insisting that he should himself do so voluntarily, followed by drill in moving the joint, effectively obliterated the memory or suggestion or hysteria that the joint could not be moved. These cases are just as likely to occur among the young and athletic as among the feeble and debilitated. The surgeon should never forget that they may occur, and should be particularly careful to distinguish them from cases of malingering. The latter is a conscious effort to simulate disease, and is usually clumsy and easily detected; but a neurotic joint is accurate in its simulation, because it depends on a persistence of the reflex nerve-muscle guard of an injured area after the real pathological condition which excited the reflex has ceased to exist. There always has been a genuine cause for these cases; it may be only slight, but nevertheless real. The higher conscious nervous system has failed to take control of the situation; the case is one for education, not punishment.

CONTRACTION OF SCAR TISSUE AND COMPOUND INJURIES ABOUT JOINTS.

The behavior of large and deep scars has been studied mainly in connection with bruises and burns. In the present

war there have been a large number of extensive wounds from shell fire and compound wounds of bones and joints with large exit wounds. Moreover, there has been added a great deal of phlegmonous and gangrenous change in the tissues, leading to considerable loss of tissue. There has, therefore, in the last nine months been ample opportunity of applying the lessons learned in civil practice and to test their truth.

It is necessary to take a brief view of the histological changes going on at the site of the wound, and to see how they are to be controlled in order to prevent stiffness of joints and mechanical disabilities due to the contracting scar.

Roughly, one may divide the process of repair, whether in epithelium, connective tissues generally, or bone in particular, into three stages.

First.—Early repair processes include the removal of dead tissues, sloughs, and necroses, and the establishment of an active hyperemia with the formation of new loops of blood-vessels permeating the mass of blood clot, exudate, and damaged tissues. In a surface wound this includes all stages up to the establishment of granulation tissue.

Second.—The second stage is that of immaturely formed repair elements, especially the laying down of fibrous tissue elements and bone elements to form cicatrix and callus. In this stage the seat of injury is still hyperemic, but as the formed elements mature, the vascularity gradually diminishes and the whole seat of repair passes gradually into the third stage.

Third.—The mature scar consists of fully formed fibrous tissue elements and hard callus. The fibrous tissue has become white owing to the disappearance of active hyperemia, and in some cases, owing to contraction of fibrous tissue, repair of other parts of the wound is impeded for want of blood.

About joints—say, the front of the wrist, the back of the

knee, the flexure of the elbow—there is a great tendency for the new scar to go on contracting until the limb is fixed in a useless, flexed position. Owing to the contraction of the scar, the bloodvessels cannot expand freely, and the whole area becomes dense, white, and anemic.

The First Stage.—During the first stage the region of the wound or injury must be left very much at rest. Fractures should be put up in the best position, torn tissues brought together so far as possible, and then left for the new repair bloodvessels to grow between fragments. These grow in the plastic exudate; therefore any rough handling, injudicious massage or movement, will only tear them.

Free exit must be given to all discharges in septic cases, that the tissues may be as little as possible sodden in poisonous toxins and as much as possible nourished and fortified by the food elements and antibodies in the blood fluids.

Therefore the surgeon should at once decide in what position the limb is to be treated, and endeavor not to move it until repair is well established.

In the Second Stage.—Passive movement is apt to tear newly formed tissues, causing bleeding and increased organization of scar tissue. On the other hand, it is possible now gently and gradually to change the position of the limb.

It is during the end of this stage, when the immature tissue elements are becoming matured, that the tendency to contract takes place; therefore if the limb has not already been put in the position opposed to the deformity which is feared, it should be done now.

For Example.—In a bullet wound through the condyles of the humerus, with extensive loss of tissue and suppuration in front of the elbow, there will be a large scar formation.

First, the fracture must be reduced, the arm put in the flexed position, and free drainage and dressing provided for.

Next, as soon as the bone becomes fixed the elbow should

be placed at a less acute angle, and as soon as possible in the extension splint shown on the diagram (Fig. 100). All this stage of treatment should be completed before the contraction of the new fibrous tissue shows itself.

Next, as soon as the union of the bone is firm enough the surgeon should risk straining the callus a little by getting the arm out to full extension and allow epitheliation to take place in this position.

In such a case there will be a large granulating surface with epithelium growing in from the side. The granulations in the center are apt to become heaped up and excessive; this should be prevented by pruning them down with scissors or even scraping them away with a sharp spoon.

The more the granulations, the bigger the mass of organized fibrous tissue formed, and the more trouble from contraction.

Skin-grafting is not to be relied on to do away with the contractility of the underlying scar tissue. Therefore the elbow should be kept fully extended until epithelium is complete and the new fibrous tissue has become adapted to the extended position, and has no longer a vicious tendency to contract.

RULES.—So far as possible, having regard to fractures, the following rules should be observed:

(*a*) The strong muscles in the axillary fold when torn by shrapnel must not be allowed to heal with a short stiff scar. Therefore the arm should be abducted.

(*b*) Wounds in the flexure of the elbow should be treated with the elbow extended.

(*c*) Burns and septic wounds of the front of the wrist and palm of the hands and fingers must be treated in hyperextension. The splint shown in diagram will be found useful (Fig. 105).

(*d*) For wounds in the flexure of the hip, the thigh should be in line with the body and a little abducted.

(*e*) In wounds in the back of the thigh the knee should be kept straight.

(*f*) The foot must in any case be kept at right angles to the leg.

Third Stage.—When wounds have already reached the contracting or fully contracted state they are not hopeless.

Continuous extension on a splint will make the scar tissue yield: daily passive stretching is of comparatively little value, for the fibrous tissue is only irritated and contracts all the more in the intervals. The extension, therefore, must be continuous. As the moorings of the scar become stretched the thin glazed epithelium over it shrinks, and the healthy surrounding skin becomes loose and stretches toward the scar, and so in time with *continuous* stretching, aided by massage, many of the most stubborn contractions, such as occur after deep burns, can be overcome and made supple.

The moral, however, is that although it may take a little longer for the wound to get covered with epithelium, it saves time and an infinity of trouble to put the limb in the stretched position at once or as early in the second stage of repair as possible.

Further, prevent excessive formation of fibrous tissue by pruning down excessive granulations. Granulations consist of loops of new capillaries, and it is along the walls of these that the fibroblasts lay down new fibrous tissue.

Fully matured fibrous tissue has no more tendency to contract than any other tissue, and as a scar takes a long time to become composed of fully mature tissue, extension of the scar must be prolonged.

The author has by steady stretching alone obtained good mobile wrists and hands in cases which had been crippled by contraction after burns for several years.

ISCHEMIC PARALYSIS.

Ischemic paralysis of the hand is a condition sometimes associated with fractures of the upper limb, chiefly about the elbow and upper forearm.

It is often associated with tight bandaging, but the paralysis may also be due to pressure from within the arm. The pressure of the broken ends of bone, the tearing of muscles followed by the formation of fibrous tissue, extensive hemorrhages, may each give rise to this condition, but it is more often associated with clumsy splints and overzeal in an effort to make them effective by tight bandaging.

It is marked by paralysis and contracture of the muscles of the forearm. It usually comes on suddenly, and the contracture is part of the initial process, and is due to partial coagulation of the proteids of the muscles, caused by lack of oxygen and blood supply. It is therefore a species of coagulation necrosis allied to rigor mortis.

Diagnosis.—The position of the hand is characteristic. The metacarpophalangeal joints are extended and the fingers are curled up. If the wrist is passively flexed, the tension of the extensors and relaxation of the flexors cause the fingers to extend without any voluntary effort on the part of the patient. Microscopic examination of the muscles shows a considerable fibrosis—it is therefore a fibrous myositis with which the surgeon has to deal.

The condition is easily distinguishable from one dependent merely on the involvement of nerve. It does not confine itself to any particular nerve-track, but generally affects all equally. Sensation is rarely lost, and muscles supplied by the same nerve may vary considerably in their involvement. The circulation is badly affected, and the nutrition shows serious damage. The finger-nails become black and the fingers mummify. The paralysis is rarely complete.

TREATMENT.—The author has long since discarded operative procedures such as lengthening of tendons or shortening of bones, as he finds that a properly conducted mechanical campaign is far more effective, if the muscles are gradually stretched, joint by joint, beginning at the fingers.

First.—An assistant passively flexes the wrist to allow the fingers to extend, and each finger is separately strapped to a little gutter-shaped splint, so that they cannot curl up.

Second.—A day or two later, or in milder cases at the same sitting, the metacarpophalangeal range is stretched and the palm and splinted fingers are bandaged to a flat metal splint. The whole hand and fingers are now rigidly fixed with the wrist flexed.

Third.—The wrist is now from day to day extended a little and fixed. This is continued until the wrist is hyperextended. This hyperextension of wrist and fingers is maintained for some time in obedience to the principles laid down concerning the extension of scars, massage being systemically practised.

The reader will note that by this simple procedure he does much more than any operation would effect. He stretches *all* the scar tissues in the direct order of their tension: those most contracted are attacked first. The muscles most infiltrated with fibrous tissue are really the seat of a diffuse scar, and the effect of continuously stretching them releases the pressure upon the vessels.

As a result the circulation of the fingers is rapidly restored, and quite soon fingers which were originally shrivelled like a bird's foot fill out and develop fatty pulp, the scar tissue becomes pliable and, where the destruction of muscle has not been too extensive, function returns.

MEASURES IN COMMON USE IN TREATMENT OF JOINT AFFECTION.

"DIRECTION OF BANDAGING.—The traditional teaching of bandaging 'from within outward over the front of the

limb,' however useful as a means of training students to obtain dexterity in handling bandages, must be abandoned when treating joints. The bandage in the hands of the surgeon is an important part of the apparatus for retaining the joint in the required position. The bandage is not a mere means of keeping a dressing in position, but should be regarded as a modified splint.

As a general rule the figure-of-eight is essential about joints and the position of crossing important. For example, in bandaging a knee to support a strained internal lateral ligament the bandage should be applied so as to check any abduction movement of the joint and so prevent tension on the injured ligament; therefore a thin pad of wool should be placed over the injured ligament and the bandages should cross to and fro over this pad. The crossings of the bandage would press on the inner side of the knee and the upper and lower loops of the eight would tend to pull the thigh and leg toward it and so keep the internal ligament relaxed.

To keep the foot everted at the ankle and relax the external ligament the bandage would cross the sole from within outward and the front of the leg from without inward; the draw of the bandage as it is put on pulls the outer edge of the sole up toward the external malleolus, and the crossing would be kept well to the outer side. To relax the internal ligament every movement would be in the reverse direction." (Jones.)

Massage and Movements in Severe Cases.—Massage as it is commonly required in connection with military surgery is very different from the heavy, vigorous massage so commonly used and so commonly needed in civil life. The overfed, physically soft individual of civil life is rarely met in the army organization, and most of the cases requiring massage are in a state of very low vitality. For the one the vigorous massage is, of course, required to stimulate the circulation, to assist in the absorption of fat and stimulate the development of the muscles; but with the other (the wounded soldier)

measures of this kind would weaken the part as well as lower the general vitality and be distinctly harmful rather than beneficial. For this reason in the military case rarely is it necessary at first to give more than very gentle kneading of the muscles, with a great deal of stroking of the skin, for the purpose of stimulating the circulation of the part through the stimulation of the superficial sympathetic nerves. It should be remembered that in a case of severe injury, with the common partial or complete paralysis, that if massage of any vigor is given, as the muscles begin their function the recovery is oftentimes retarded, if not entirely prevented. Much benefit is obtained, however, from gentle stroking, with the encouragement of the voluntary function of the muscle. The amount of physical force expended in treatment of this kind by the manipulator is, of course, much less than that commonly expected to meet the civil needs. In conditions of this kind it should be remembered that in encouraging active use of the muscles, care should be taken not to overuse the part. A muscle that has been inactive for any length of time from division or from bruising of the nerves is made up largely of degenerated fibers, and when the nerve impulses first begin to return the muscle will have the recovery retarded or even prevented altogether if used much or subjected to massage of any real vigor. If, however, at such times, with the gentlest massage and stroking of the skin, slight use of the muscles is encouraged, benefit will result. In such use the movement that is part of such muscular effort, such as flexion of a joint, should be assisted so that no undue strain upon the muscle is made, and the motion should not be repeated more than three or four times at first. The amount of work should be increased gradually both as to the strength of the effort made and the number of times that it is to be repeated, with frequent periods of two or three days at a time at first in which no treatments whatever are given. By such careful handling many cases that would ordinarily be hopeless may be restored to usefulness.

Contrast Baths.—This consists of the alternate application of as hot water as can be borne and of as cold water as is procurable. A rapid dilatation and contraction of the bloodvessels is produced, which, besides relieving the pain, improves the local vascular and nervous tone very markedly.

Method.—In the simplest method of application two buckets are used; if the part to be treated is a hand or foot, it is "plunged first into one and then into the other as fast as the patient can change it for five to ten minutes; in other parts two sponges (or cloths) may be used, one for hot and one for cold water." When running water is available a spray of the ordinary bathtub pattern is preferable, the hot water being used for one or two minutes and the cold for fifteen to twenty seconds, both being repeated for ten minutes or more; in this method is secured the additional stimulation resulting from the impact of the water.

Indications.—Ordinarily of special value in the later treatment of acute affections and in many subacute and chronic ones when such stimulation is required. It is important that a good reaction be secured, and that the part be left warm. With marked or brawny infiltration and with effusions baking is preferable at first.

Elastic Pressure.—*Method.*—Elastic pressure may be applied by means of elastic bandages of various sorts, or by a thick cotton or wool dressing over which a roller bandage has been applied.

Bandages containing rubber are not advisable for routine treatment; a cheap and efficient elastic bandage is that made of flannelette, or flannel if available, cut on the bias in strips from three to five inches wide and sewed together with a flat seam to make a bandage from three to five yards long. Bandaged around the part snugly this gives excellent elastic pressure and also fixation in proportion to the number of layers used.

Another excellent, and in many cases preferable, method

is the following: First cover the part evenly and smoothly with from four to five layers of cotton (the waste absorbent roll cotton will do, but ordinary cotton as used for quilting is best) and "then bandage firmly over this, taking care that the bandage is running in the right direction to maintain the desired position;" in applying the bandage, leave a half-inch to an inch of the cotton projecting at each end. The more layers of cotton that are used the tighter the bandage can be applied without danger of undue constriction. When the bandages loosen from decrease of swelling, or other causes, it is not necessary to remove it but another one is applied over it, with more cotton if needed, and so on. After a time reapplication of the entire dressing may be required.

Indications.—To promote absorption and check bleeding; of particular value in the immediate treatment of acute injuries and sprains when great swelling is to be expected.

PASSIVE MOVEMENT.—The best American opinion is in agreement with that of Jones that passive movement "should practically be limited to forcing a free path for movement which are obstructed by adhesions. When adhesions are thus broken down under an anesthetic the process should be thorough, and, if possible, carried on by one firm movement. . . . Having broken down adhesions it should be sufficient to put the joint through its full range of movement once a day, and once only, until the patient can perform the movement voluntarily." Passive movement is, however, not usually so understood. It is often advised carelessly without regard to the anatomical and pathological conditions of the joints involved, and under such conditions results are often disastrous, especially in inflamed joints and in many forms of infected joints, as well as injuries, fractures, and dislocations at or near the joints, and seldom if ever is any good accomplished by such attempts to establish normal motion. (Gillette.)

CHAPTER V.

DISABILITIES OF THE KNEE-JOINT.[1]

EVERY kind of disability of the knee-joint may occur in military practice, from a simple sprain to the results of a severe wound.

An attempt will be made in this chapter to give a broad classification of these derangements and disabilities, with their diagnostic signs, and to indicate appropriate lines of treatment.

There are three common conditions which are not always as clearly distinguished by practitioners as they might be. They are (1) simple sprain of the lateral ligament, usually the internal; (2) slipping of the semilunar cartilage; and (3) nipping of the infrapatellar pad of fat. All these injuries may be produced by a twist or fall which at first does not seem serious; all are associated with effusion of fluid in the joint, and in all the patient complains of more or less recurring disability after the lesion, unless it has been recognized and treated in the first instance.

SPRAIN OF INTERNAL LATERAL LIGAMENT.

Sprain of the internal lateral ligament is distinguished by definite pain and tenderness on pressure over the attachments of the internal lateral ligament; the patient himself localizes the pain of which he complains to the inner side

[1] This chapter is taken from "Notes on Military Orthopædics" by Col. Sir Robert Jones.

of the knee; definite pain and tenderness are not found anywhere else about the knee, and the movement of eversion and external rotation of the leg stretches the injured ligament and retards recovery.

The *treatment* indicated, therefore, is firm strapping round the knee in order to steady it, and a raising of the inner side of the heel to divert body weight to the outer side of the foot, and thus relieve the ligament from tension. It is hardly necessary to say that this treatment is preceded by rest in bed, usually with the aid of a straight posterior splint. This is the initial treatment, but neglect of the after-treatment just mentioned renders the patient liable to recurring injuries of the ligament.

INTERNAL DERANGEMENTS OF THE KNEE.

A regular gradation of injuries is met with, from a slight strain of the attachments of the internal semilunar cartilage of varying degrees of gravity to fractures of the spine of the tibia with rupture of the crucial ligaments. The former is a condition scarcely distinguishable at first sight from a simple sprain; the latter is at once obvious as a grave disability. It has become very important in military surgery to be able to distinguish these conditions clearly by signs which can be determined by the surgeon rather than by symptoms described by the patient; as in my experience, a considerable number of men who wish to avoid service have found that they can puzzle the medical officer by complaining of obscure pain and disability in the knee.

There are very many cases in which military surgeons have been led to operate upon a normal joint, expecting to find some abnormality of the semilunar cartilage. The cartilage is very frequently torn in its posterior portion, and before deciding at operation that it is not damaged it

is necessary to dislodge it outward. Hence the necessity for careful consideration of symptoms before deciding to operate. It must be realized that exploration, in the case of a cartilage, really involves its removal, otherwise a damage at the posterior part of the cartilage may be overlooked.

MECHANISM OF CERTAIN INJURIES.—Probably the best way in which to get a clear idea of the injuries which lead to error is to consider the mechanism of the various injuries, beginning with simple sprain and going on to real rupture or tear of the semilunar cartilage, and to compare them with bruising of the infrapatellar pad of fat, which is a lesion not always recognized or understood.

All these conditions may lead to a recurring chronic synovitis. Every case of recurring synovitis has a cause, and practically each is curable if the cause is recognized and receives appropriate treatment.

It has already been stated that simple sprain of the internal lateral ligament is marked by a specially tender spot over the attachments of the ligament and nowhere else.

RUPTURE OF INTERNAL LIGAMENT AND DAMAGE TO THE SEMILUNAR CARTILAGE.—If we remember the anatomical fact that the internal semilunar cartilage is closely connected round its convex margin with the deepest layers of the internal ligament and with the capsule of the knee-joint, we shall understand why a severe twist of the knee, with the leg abducted, may rupture the ligament and drag the semilunar cartilage with it, straining or tearing the attachments of the anterior horn. At this stage the inner side of the knee-joint is, so to speak, opened out, and everything depends upon what happens when it closes again as soon as the distorting force ceases to act.

If the cartilage is caught in displacement between the bones the knee "locks" in the manner familiar to us all. The cartilage may be split, fractured transversely, rolled

up, or completely torn from its attachments. A perusal of the literature of the subject, indeed, shows that every conceivable injury to the semilunar cartilage may take place, and such cases have often been fully described. Sometimes the cartilage slips back into position without being crushed or caught between the bones; there is then no locking of the joint, but, in every respect, the etiology of the lesion is the same with the exception of the actual injury to the cartilage, and the patient generally states that he felt something "slip" or "click" in the knee, but could quite easily straighten it immediately after the accident.

The history suggests the usual cartilage injury of text-books but without locking; the knee becomes distended with fluid, and the patient refers his pain to the inner side. The physical signs are tenderness on pressure over the internal lateral ligament, and a specially tender spot to the inner side of the ligamentum patellæ just over the border of the tibia, a symptom always strongly suggestive of an injury about the attachment of the anterior end of the internal semilunar cartilage.

The treatment of the condition when the knee cannot be fully extended without causing pain will be discussed later. If the knee can be fully extended without causing pain, the aim should be to ensure complete rest until the torn attachments have united. The knee should be kept absolutely straight on a back splint for at least ten days, the bandage being firmly applied over cotton-wool. After this the patient may begin to walk, and when he does so he should have a firm bandage over the knee to prevent effusion into it. Movements of the joint should be very limited the first day, and should gradually increase in range.

A common fault in treatment is to allow the patient up without a proper protective bandage on the knee, the

result of which is effusion into the joint, and, what is more harmful, into the newly formed cicatrix about the anterior horn of the semilunar cartilage, thus stretching the newly formed scar and letting the end of the cartilage shift about. When this happens the patient is often put to bed for a week until the effusion has disappeared, but when he gets up again, the effusion recurs, and so he goes on week after week, until finally the attachments of the anterior end of the cartilage become elongated and slack. The patient then complains that occasionally he feels a "give" in the knee, but it does not "lock." Some day a slight unusual twist may result in a real locking of the joint.

A joint such as this which has been the seat of a definite injury will generally fill up with synovial fluid when first used. Therefore the application of a pressure bandage should never be omitted. If the knee is carefully brought into use by graduated exercise, there should never be much effusion, and each day it should be less in amount; that is to say, there is no effusion in the morning, although by the end of the day it may have appeared, and each evening the amount is less than on the preceding one.

THICKENED CICATRIX ABOUT THE SEMILUNAR CARTILAGE. —If the effusion does not become progressively less, either the patient is using the knee too much and moving it too roughly, or some injudicious masseur is moving it too roughly for him, or the surgeon has made a mistake in his diagnosis and there is some condition in the joint which requires further attention, and he should make a careful examination and reconsider his opinion of the case. When these cases have been the victims of defective after-treatment, repeated stretching and effusion about the anterior end of the semilunar cartilage gives rise to a thickened cicatrix, which is tender, and can sometimes even be felt by the surgeon moving under his finger as the knee is flexed and extended. This painful spot is situated at the diagnostic point, already

described, on the front of the knee, well to the inner side of the ligamentum patellæ. Sometimes this cicatricial thickening is so great that it is pinched between the bones when the knee is fully extended, and this causes sharp, well-localized pain and tenderness.

Treatment in such cases depends upon the exact condition, and two types must be distinguished:

1. In cases in which the cicatrix is not pinched, but merely gives rise to a sense of insecurity as if something is moving or "clicking" inside the joint, a rigorous course of strict rest, followed by massage and carefully graduated exercises, may cure the condition in a month.

2. In cases in which the cicatricial mass gets definitely nipped, the condition has become similar to the type of displaced semilunar cartilage usually described, and if rest and careful exercise fail, an operation to remove the whole mass is indicated—the opportunity being taken to inspect the cartilage at the same time.

Displaced Cartilage with "Locking."—It has long been recognized that definite locking of the knee-joint is a characteristic sign of displacement of the internal semilunar cartilage, as described in text-books. This condition is a more severe variety of the injury just described; it differs from it in the fact that some portion of the cartilage is, for a time at least, caught between the bones and prevents full extension.

The treatment of this condition aims at the restoration of the power of extending the knee fully without pain.

If the displaced cartilage is fully reduced the knee can be fully extended, both actively and passively, without pain. If this cannot be done, the cartilage is not reduced. When the cartilage becomes disengaged the patient is aware of it—in fact, he is the most competent judge of the success or failure of the manipulation.

Treatment of the Initial Injury.[1]—First, complete reduction is necessary. This can usually be effected by manipulation without the use of force, and the routine I prefer involves the active assistance of the patient. The patient should lie on his back with the thigh flexed on the body and the leg on the thigh. When in this position the surgeon can manipulate the leg, and can sometimes feel a fulness over the site of the displaced cartilage.

The patient is then told that he will be given the word "One, two, three—*kick!*" On the word "kick," the patient extends the limb as suddenly as he can. At the same time the surgeon rotates the foot inward and pulls, while pressure is placed upon the thigh. If the dislocated cartilage is reduced, the patient is almost certain to announce the fact, and the objective sign is that the knee can be completely extended without impediment. The knee, surrounded by wool, should be bandaged firmly, and fixed on a posterior knee splint. If the patient is not of a temperament likely to be helpful, an anesthetic is advisable.

Our next effort is to secure the healing of the lesions in and about the cartilage, so that it may have a chance of adhering in its proper position. The patient should therefore wear the splint for about ten days, but can usually be allowed up in his room at the end of five days. After ten days he may walk with the knee bandaged, taking care

[1] *Editorial Comment.*—Another method which does not require the assistance of the patient is the following: The patient lies on a table with the affected knee flexed over the side. If it is the right knee and the internal cartilage is displaced, the operator places his left hand under the thigh just above the knee and grasps the ankle with his right, while an assistant holds the thigh firmly with his two hands to prevent it from rotating. The operator then (1) flexes the knee fully, (2) twists the lower leg forcibly in outward rotation on the femur, at the same time (3) carrying the ankle outward so as to press the outer tuberosity strongly against the outer condyle and open up the space between inner tuberosity and condyle, and (4) suddenly straighten the knee fully.

not to bend the knee suddenly. Active flexion of the joint should be practised very gradually, and the quadriceps muscle should be massaged and exercised gently. If the progression is carefully made from gentle to stronger movements, the full range should be recovered without the recurrence of any effusion in the joint in about three weeks. The majority of these cases, carefully and efficiently treated in the first instance, do not give any further trouble.

Where a successful reduction is not accomplished, and, in consequence, the patient is not able to extend the knee fully, an operation will probably be required.

Cases of Imperfect Reduction.—I see many cases two or three weeks or more after the accident, in which it is obvious that attempts at reduction have either not been made or have failed. The surgeon in charge of the case may have thought that he had got the knee fully extended, but passive extension still caused pain, localized over the anterior end of the cartilage; the knee filled with fluid when the patient walked, and though comparatively free from pain after rest, it became tender after exercise. It is often possible, even after weeks of displacement, to reduce the cartilage in these cases by manipulation similar in kind but more forcible than that necessary in dealing with the original injury. This manipulation forces the displaced cartilage from its abnormal to its normal position, where it may become firmly and accurately fixed. This late reduction so often succeeds that it is always worth trying. If, after an attempt at reduction under anesthesia, the cartilage still remains in a position in which it gives trouble, or if it remains loose and frequently gets nipped, operation is the only sure treatment; for the case now has become one of recurring dislocation of the semilunar cartilage with locking of the joint.

A word of warning may here be given about cases in which reduction is apparently complete, and the patient

can get about with tolerable comfort, but complains that the knee-joint does not feel quite secure, although there is no evidence of the intrusion of any structure between the bones. These symptoms are often due to some minute adhesion within the joint which does not produce sufficient limitation of movement to be detected by the surgeon, but leaves the patient with the sense that he cannot use the joint without a feeling of restraint. Full movement of the joint, particularly in rotation, under gas anesthesia, will often remove these symptoms, although the surgeon cannot always feel any definite adhesion give way during the manipulation.

Operation on the Internal Semilunar Cartilage.—It is needless to say that the knee should never be opened except under the most scrupulously aseptic conditions, and never in a hospital in which there are a large number of septic cases. Operations on cartilages, even at base hospitals at the front, should be discouraged. It is not a practice which can be recommended, as the environment is a source of danger, no matter how experienced the surgeon.

The procedure which I prefer is the following: The leg is placed to hang over the end of a table at right angles to the thigh; the knee is wrapped in sterile gauze, soaked in biniodide solution; the incision is made through the gauze, and the edges of the gauze clipped over the skin edges to the superficial fascia. As the knife with which the skin is cut may become infected by *Staphylococcus albus*, a second clean knife should be used for all the deeper dissections. The incision need not be more than an inch or an inch and a half in length; it is made over the anterior end of the cartilage, sloping very slightly downward and inward—that is, nearly, but not quite, parallel to the upper edge of the tibia (Fig. 12). Great care should be taken never to allow the incision to extend far enough to the inner side to cut any fibers of the internal lateral ligament; this is a

fault which leads to weakness of the knee lasting for months or years, and is, unfortunately, still frequently to be met with in cases which have been operated on by the old large J-shaped incision described in text-books. The joint being opened, a blunt hook can be slipped under the free margin of the cartilage, and by picking it up it can easily be seen whether the front part is intact or torn, or has tags or

FIG. 12.—Showing position of incision.

projections producing disability. In removing the whole cartilage great care should be taken that no tags of cartilage are left projecting from the attachment to the coronary ligament, as these frequently give rise to continued symptoms, due to nipping or adhesions, and may necessitate a second operation. The condition of the fringes should be examined before closing the knee, and by retracting the patella the opposite front part of the cartilage can be

inspected, if this be deemed necessary. No movement of the knee must be allowed after the incision has been made, as this may favor the entrance of air—a minute risk, but an avoidable one, and therefore one which the surgeon has no right to take. It is not until the stitching is complete and pads are placed over the wound that the knee is straightened. Dressings are then applied, elastic pressure is put on by bandaging over large pads of wool, and a simple posterior knee splint affixed to keep the knee straight. If the operation is performed with a tourniquet around the thigh—and this is advisable—no vessels need be tied; and if the elastic pressure is applied before the tourniquet is removed there need be no fear of bleeding into the joint. My experience of these operations now extends to over 2000 cases, and I feel that I can speak with some authority.

After-treatment.—In a straightforward case there is no reason why the patient should not get out of bed onto a couch on the third or fourth day. He should not, however, put his foot to the ground for the first week. The stitches are removed as usual about the tenth day and massage may be commenced, the patient being allowed gradually to bend his knee. Each day he exercises, bending and extending the knee more and more, until in about three weeks he should reach the full range of movement and walk with freedom. In my practice several professional footballers have resumed their game in six to eight weeks after the operation. There is no reason why in suitable cases men should not return to light duty about five weeks after the operation, and, if properly exercised, be fit for full duty three weeks from that date. This, however, depends upon the patient being put through a course of carefully graduated movements and exercises during the whole period of his convalescence.

Surgeons who have been operating upon soldiers complain of the weakness in the knee which so often follows operation. This experience is common, but if the opera-

tion has been properly performed and the after-treatment by massage and exercise has been thorough, these disappointments will not occur. The surgeon should be assured that the thigh muscles are restored to their normal condition, and a patient should not be discharged from hospital until the thigh has attained its normal girth. We must also retain a critical attitude of mind, for some soldiers are keen to remain off duty, and the knee is often only an excuse.

RECURRENT EFFUSION INTO THE KNEE-JOINT.

Recurrent effusions into the knee-joint are often very puzzling. It is possible, however, to lay down a few rules for guidance.

1. After injury of the knee, effusion of fluid into the joint is very liable to occur, and if the patient is kept resting and not using the limb, the effusion will probably recur the first time he uses it. The patient is again put to bed, but when he gets up effusion reappears. The rational treatment in such cases is to bandage the knee firmly and let him walk, and in the evening there will be some effusion which will disappear by morning. The knee should again be bandaged and the patient allowed to walk. In the evening there will still be effusion, but not so much as before. By following this routine the joint will gradually become accustomed to the increasing exercise, with a diminishing amount of effusion on each day. This is the real test that a joint which has been injured is really recovering and is fit for gradually increasing exercise.

2. The second point is that recurring effusion which increases instead of diminishes under the above careful treatment is a sure indication that the joint is not fit for use, and localizing symptoms and signs should be searched for to find what is the precise cause of the disability.

3. Recurring effusion which is associated on each occasion with some slight mishap—a trifling strain, such as a twist of the knee, a feeling that something has slipped in

the joint, or definitely localized pain—is rather an indication that there is some definite body loose in the joint which is occasionally getting nipped, though not retained long enough in one position to produce "locking." The surgeon should then decide whether it is an enlarged pad of fat, a loosened cartilage, or a loose "body," or a portion of the cartilage left after operation.

DISLOCATIONS OF THE EXTERNAL SEMILUNAR CARTILAGE.

The symptoms associated with accidents to the external semilunar cartilage are much less clearly defined than those associated with injury of the internal cartilage. One reason for this is that the external cartilage is not attached to the external lateral ligament of the joint, and there is no definite mechanism by which it is pulled out of place. "Locking" may occur, the pain being referred to the front or back portion of the outer part of the knee according as the anterior or posterior end of the cartilage is torn from its attachment or crumpled up. Cases occur in which both cartilages are displaced by one injury, suggesting that it is only a rather more severe accident than that usually associated with the displacement of the internal cartilage which damages the external one also, the mechanism probably being a lateral sliding of the condyle on the top of the tibia, squeezing the cartilage out of place and tearing its attachment.

RUPTURE OF CRUCIAL LIGAMENTS.

In more severe accidents to the knees the displacement of the tibia on the femur may be sufficiently great to cause rupture, not only of lateral ligaments, but of the intrinsic ligaments of the joint. This may or may not amount to what may be described as complete dislocation. Experience of cases of dislocation of the knee-joint, in which of necessity all the ligaments have been torn, proves that with appropriate rest in a correct position an astonishingly good

result can be obtained. When called on to treat a serious accident such as this, the practitioner's instinct is to get the limb straight and to keep it fixed for a long time. It is when the accident has been less than a complete dislocation that one is liable to think that less strict treatment may suffice. Consequently cases are met with in which the patient suffers from abnormal mobility of the knee-joint, clearly indicating that one or both of the crucial ligaments have been ruptured or stretched. Bearing in mind the mechanism of the crucial ligaments, it is not difficult to make a diagnosis.

1. The anterior crucial ligament is tense when the knee is fully extended, and prevents the tibia from being displaced forward on the femur.

2. The posterior crucial ligament is tense in complete flexion, and prevents the tibia from being displaced backward on the femur.

3. Both ligaments check inward rotation of the tibia. Hence, if the tibia cannot be displaced forward in the extended position, it may be assumed that the anterior crucial ligament is not completely torn; and if the tibia cannot be displaced backward in full flexion, the posterior crucial ligament is presumably not ruptured. Abnormal mobility indicates elongation or rupture of the corresponding ligament. The history of an injury helps the surgeon to exclude cases in which prolonged distention of the joint with fluid has caused elongation of all the ligaments, as well as the conditions associated with diseases such as Charcot's disease or locomotor ataxia.

The treatment, when any such condition is diagnosed, is prolonged rest with the knee in extension, or fixed in plaster, or a Thomas calliper splint, in which the patient can walk, the object being to keep the joint immobilized for a time long enough to allow union of the torn ligaments or adaptive shortening of stretched tissue. The operation of stitching the ligaments is absolutely futile as a mechanical

procedure. Natural cicatricial tissue, allowed to mature without being stretched, is the only reliable means of repair.

FRACTURE OF THE SPINE OF THE TIBIA.

The mechanism of this accident appears to be the following: The knee is subjected to violent torsion such as might produce a dislocation or rupture of the crucial ligaments; at the time when the force is applied the condyle of the

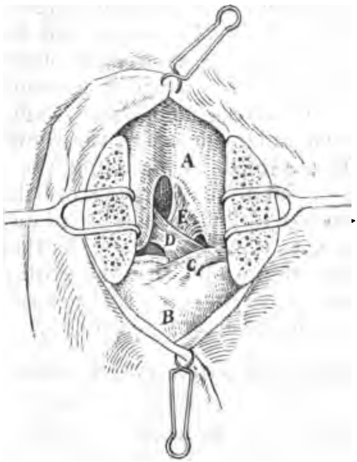

FIG. 13.—Showing patella split: *A*, femur; *B*, tibia; *C*, transverse ligament; *D*, anterior crucial ligament; *E*, posterior crucial ligament; *F*, cut halves of patella. (Jones.)

femur grinds across the surface of the tibia, and the sharp intercondylar margin shears off the spine. In some cases avulsion of the spine occurs instead of rupture of the crucial ligaments. The displaced fragment of bone may be lodged in the front part of the knee-joint, and so prevent its full extension. Diagnosis is verified by *x*-ray examination.

Symptoms.—The most constant symptom is a somewhat rigid block to full extension, usually accompanied by pain behind the patella.

Treatment.—If the knee can be fully extended, the displaced fragment of bone being presumably pushed back somewhere between the condyles, the knee should be fixed in this position for a long period to allow the torn structures to reunite. On the other hand, if the displaced fragment blocks extension, and the surgeon cannot manipulate it back into a harmless position, or extend the knee even by moderate force, it is best to remove the obstructing fragment of bone, fixing the knee afterward in a straight position, and leaving Nature to effect her own repair. The surgeon must use his own judgment as to the route he adopts; the freest access is obtained by splitting the patella longitudinally (Fig. 13), but if the x-ray shows that the offending fragment of bone could be reached by an incision at the side of the patella, this is a less severe method of procedure. As I am largely responsible for the split-patella route in dealing with unusual derangements, I am anxious to emphasize that it is only needed in exceptional cases.

THICKENED RETROPATELLAR PADS OF FAT.

Almost any injury of the knee which is associated with increased vascularity or bruising may give rise to swelling of the pad of fat situated behind the patellar ligament. Consequently this fat is liable to be nipped in full extension of the knee. In ordinary civil life this forms one of the varieties of the initial stage of a local monarticular rheumatoid arthritis. The condition, however, is in no sense rheumatic. The patient complains of pain and tenderness in the knee after walking, and especially when going up and down stairs, or when getting up suddenly from a chair after sitting for any length of time. The condition is maintained by the repeated small injuries which occur every time the knee is fully extended. The treatment therefore is obvi-

ously to prevent the patient from inflicting small bruises on the tender fat and its covering of synovial membrane. This can easily be done by putting a cork pad, half an inch thick, inside the boot under the heel, to prevent the complete extension of the knee during walking, and by fitting the knee with a cage support (Figs. 14 and 15),

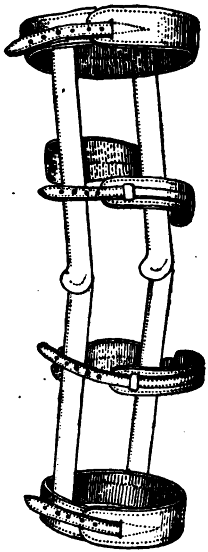

FIG. 14.—Cage support for knee. (Jones.)

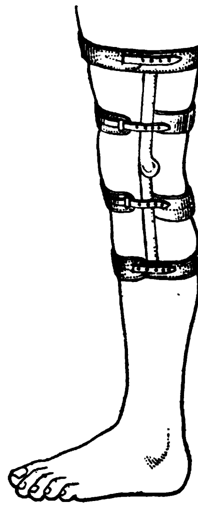

FIG. 15.—Cage support for knee applied. (Jones.)

which allows full flexion but limits extension by about 30 degrees. When wearing this boot and cage splint the patient cannot fully extend the joint and in this way bruise the postpatellar fat. The swelling gradually disappears, and after a few weeks full extension can be performed without pain. The diagnosis of the condition is easy. The

patient complains of pain in the knee, or, more often, in front of the knee, not at the inner side. Passive extension of the knee by the surgeon produces the pain which is definitely localized just below and behind the patella. On palpation the thickening of the pad of fat may be felt; it is enlarged and tender, but there is no sensitiveness over the internal cartilage or the internal lateral ligament. In some instances the retropatellar pad of fat may be bruised in common with injury to the semilunar cartilage. The full tender point of the internal lateral ligament, cartilage, and fatty pad will be found in such a case.

In all the injuries of the knee which I have been discussing, wasting and weakening of the quadriceps muscle is a characteristic feature, and no treatment can be regarded as sufficient which does not provide for the restoration of the efficiency of this muscle during the stage of convalescence. This is particularly to be noted in the condition which is now under discussion, for some of the deep short fibers of the subcrureus muscle are inserted into the synovial membrane of the joint, and when they contract they draw up the synovial membrane and help to pull the pad of fat out of danger when the knee is extended. Neglect, therefore, of the quadriceps muscle will leave the patient peculiarly liable to a recurrence of the injury.

If the reader has appreciated the regular gradation of disorders of the knee already described, he should have little difficulty in applying and adapting the method of diagnosis and treatment to unusual types which occur as a result of injuries in military service. Even bullet wounds through the joint, which sometimes chip off fragments of bone, can be dealt with on lines similar to those indicated for fractures of the spine of the tibia. The whole question of septic arthritis in and about the joints, with resulting ankylosis, is a larger subject, which cannot be dealt with in these pages.

CHAPTER VI.

POSITIONS OF ELECTION FOR ANKYLOSIS FOLLOWING GUNSHOT INJURIES OF JOINTS.[1]

THERE are certain injuries to joints occurring after gunshot wounds which must inevitably end in bony ankylosis. From their very nature some of these will not admit of excision.

When a joint has been shattered, and the muscles governing it have been in part or wholly destroyed, excision is not merely difficult from the point of view of surgical technic, but often results in a flail articulation which renders the limb quite useless. This is especially the case when such joints as the shoulder, elbow, and wrist are concerned. Excisions of the upper part of the humerus are frequently practised as a conservative procedure in the presence of acute or persistent sepsis, especially at the French front. This may be very necessary, but the resulting condition will at a later date require further surgical intervention. The question has often been put to me: "What should be done with these flail-joints, and, if ankylosis is to be expected, in what position should the joint be placed in order to be of the greatest use to the patient?" The question as to flail-joints will be considered at the end of this chapter, but in the first place it may be of service to indicate briefly

[1] This chapter is taken from "Notes on Military Orthopædics" by Col. Sir Robert Jones.

the conclusions as to the positions for ankylosis to which experience has led me.

SHOULDER-JOINT.

POSITION.—The arm should be abducted to about 50 degrees (Figs. 16 and 17). The elbow should be slightly in front of the coronal plane of the body (Fig. 17), so that

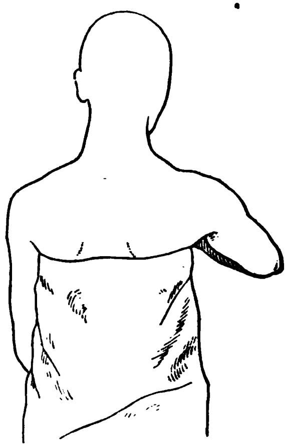

FIG. 16

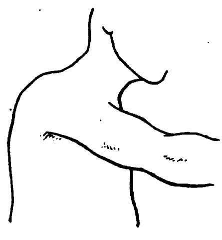

FIG. 17

To illustrate the position for ankylosis of the shoulder in abduction. (Jones.)

when it is at right angles and the forearm supinated, the palm of the hand is toward the face. The arm is placed in this position while the scapula retains its normal position of rest.

REASONS.—If the arm be correctly placed, the hand (Fig. 18) can be brought easily to the mouth by bending the elbow. Further, the humerus being fixed to the scapula

at the angle indicated, the arm can be lifted to a considerable height by scapular action (Fig. 19); moreover, pockets can be reached, the hair brushed, and the patient can pick up a plate or cup without spilling the contents.

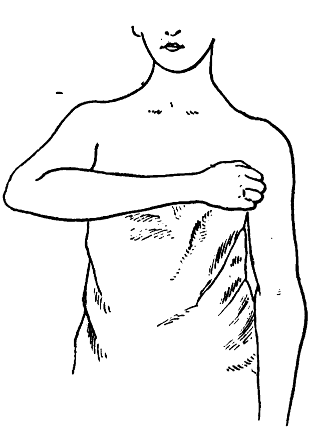

FIG. 18. — Ankylosis of the shoulder in abduction to show degree of abduction. (Jones.)

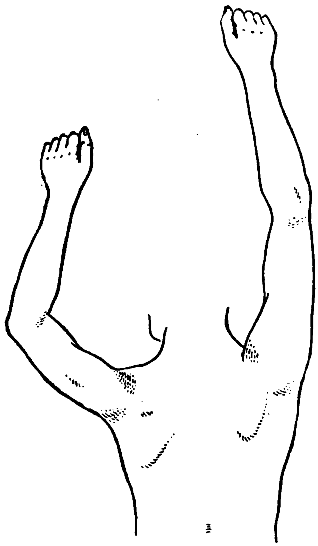

FIG. 19.—The degree of power of lifting the arm. (Jones.)

The arm should never be kept to the patient's side if ankylosis is feared, for in such a case the functional result must be most unsatisfactory; not only will it be difficult to reach many parts of the body, but difficult also to reach across a table or to perform many simple movements constantly recurring in every-day life. Flail shoulder-joints also should be ankylosed in the position described, and joints

which have been allowed to ankylose in an adducted position (Figs. 20, *A* and 20, *B*) may require osteotomy of the humerus high up to correct this faulty position. The shoulder-joint should never be allowed to become fixed at right angles to the side in adults, as in that case the patient will be unable to bring his arm down to his side.

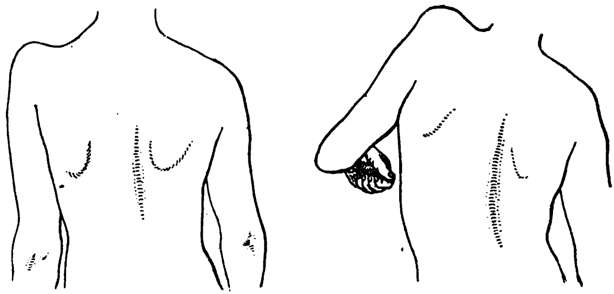

FIG. 20, *A* FIG. 20, *B*

Fig. 20, *A* shows faulty adducted position of arm, and Fig. 20, *B*, the consequent extremely limited power of abduction. (Jones.)

It is to be clearly understood that I am dealing with injuries to soldiers and sailors, and not with children, in whom other means can be adopted owing to anatomical considerations.

ELBOW-JOINT.

POSITION.—The proper course to adopt will depend upon the patient and his calling, but by far the greater number of men would prefer the fixation to be at just below a right angle—that is, about 70 degrees (Fig. 21). The ankylosis commonly met with at 130 degrees is not useful. It is important to bear in mind that in cases in which *both* elbows will become ankylosed it is necessary to fix the one at an angle of 110 degrees, and the other at 70 degrees as recommended for one-sided trouble (Fig. 22).

REASONS.—This position enables the patient to move his hand to his mouth, button his clothes, brush his hair, and reach over a table. At an angle less than a right angle it is certainly more easy to get the hand to the mouth and to various parts of the head, but limitations in other directions more than counter-balance these advantages.

FIG. 21.—Ankylosis of elbow-joint at 70 degrees. (Jones.)

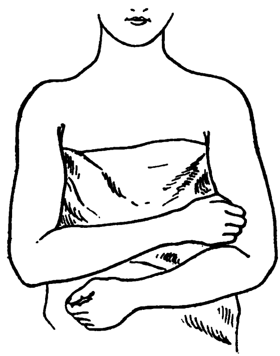

FIG. 22.—Right elbow at 110 degrees, left elbow at 70 degrees. (Jones.)

FOREARM.

POSITION.—If the movements of pronation and supination are lost, the radius should be fixed midway between pronation and supination.

REASONS.—The hand is more useful for dressing and eating and for manual labor in this position. A minor advantage is that of appearance.

WRIST-JOINT.

POSITION.—All injuries of the wrist-joint should be treated with the wrist dorsiflexed (Fig. 22).

This is a priceless surgical axiom, the neglect of which is grave

It is an urgent necessity where ankylosis is expected, or where even limitation in movement is likely to occur.

The common deformity of palmar flexion occurs when no splint is applied, or from the use of a straight splint; in all cases in which the arm and fingers are kept on such a splint, palmar flexion of the wrist occurs, and this condition is a life-long handicap to the usefulness of the hand.

Reasons.—The grip of the fingers is diminished if the wrist is palmar flexed. The strong flexors overpower the extensors of the fingers, and in consequence proper coördination of the finger movements is impaired. The grasp of the hand is strongest when the wrist is in the dorsiflexed

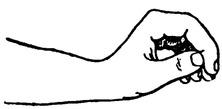

Fig. 23.—Dorsiflexion of the wrist. (Jones.)

position, the balance between the flexors and extensors is better preserved, and the coördinated movement of the fingers is secured.

The splints required are simple.

In proof of the importance I attach to the dorsiflexed ankylosed wrist, I may state that I always restore hyper-extension of the ankylosed joint from the position of flexion by manipulation or incision. This invariably improves the grip of the fingers.

Apart from the impairment of function, a flexed wrist is unsightly.

HIP-JOINT.

Position.—Ankylosis should be encouraged in a position of very slight abduction, with thigh extended and very slight outward rotation (Fig. 24).

Reasons.—The common deformity in ankylosis of the hip is flexion, adduction, and internal rotation (Fig. 25), which is the characteristic position we find in an untreated or

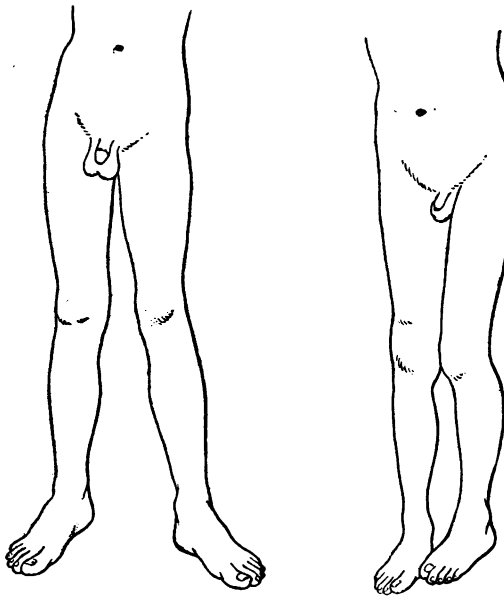

Fig. 24 Fig. 25

Ankylosis of hip. Fig. 24, correct position, in slight abduction with extended thigh and slight outward rotation. Fig. 25, faulty position of ankylosis in flexion with adduction and internal rotation. (Jones.)

imperfectly treated tuberculous hip-joint; it leads to lumbar lordosis and an ugly limp. Adduction deformity brings the limb too near the middle line, interferes with the normal

position of the sound limb in walking, and, by involving abduction of the sound limb, interferes also with a free gait.

If the hip-joint is ankylosed in the fully extended position, lordosis and the consequent trouble from backache are avoided, and there is freer pelvic movement in walking if the thigh is slightly abducted.

The limb should be very slightly rotated outward to avoid the unsightly lift of the pelvis as the patient rises on his toes when walking, due to the immobile condition of the hip-joint. This gives an easier walk than if the toes are pointed straight forward.[1]

KNEE.

POSITION.—This joint should be fixed in an extended position.

REASONS.—Very good reasons may be given in favor of slight flexion from the point of view of elegance in repose and that of ease in mounting stairs. Due weight should be given to these arguments, but in the case of war injuries the straight position obviates many risks. Ankylosis, as we know, is not necessarily bony; when it is fibrous the tendency is for the flexion angle to increase by exercise. The incidence of the body weight on a slightly bent knee, unless the ankylosis is sound and bony, will increase the flexion. The position therefore is mechanically a weak one for carrying body weight. Even when new bone is forming, its complete consolidation is sometimes a slow process, and if the surgeon places such a knee in a slightly flexed position the degree of ultimate flexion is often much greater than he would wish. The advantage of increased strength and stability ensured by an extended joint will generally outweigh all other considerations.[2]

[1] *Editorial Comment.*—Most American orthopædic surgeons prefer 10 to 15 degrees of flexion at the hip.

[2] *Editorial Comment.*—Most American orthopædic surgeons prefer 20 to 25 degrees flexion at the knee.

ANKLE.

POSITION.—The foot should be kept at a right angle with the leg, so that the sole impinges on the ground in a slightly varus rather than a valgus position (Fig. 26).

FIG. 26.—Ankylosis of ankle with foot at right angle and sole in a slightly varus position. (Jones.)

REASONS.—If the reader will recall the ankylosed ankles he has seen, he will remember that most of them were in a valgoid position. A varoid position conduces to a strong type of foot; a valgoid (flat foot) to a weak foot, and all the disability associated with erroneous deflection of body weight.

JOINTS OF THE TARSUS AND METATARSUS.

In gunshot wounds and other injuries of the tarsus and metatarsus, the deformities to be feared correspond to the common static deformity of flat or pronated foot—a subject

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which is dealt with at greater length in Chapter III—that is to say, to pronation at the midtarsal joint, flattening of the longitudinal arch, and sometimes flattening of the transverse arch associated with pain in the metatarso-phalangeal joints. Callus exudation added to plantar malposition results in a very crippled foot. In all gunshot injuries of tarsus and metatarsus the surgeon should take care during the later stages of healing not to bandage the

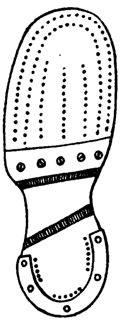


FIG. 27.—Boot with bar behind head to relieve injured metatarsal joints and phalanges from pressure. (Jones.)

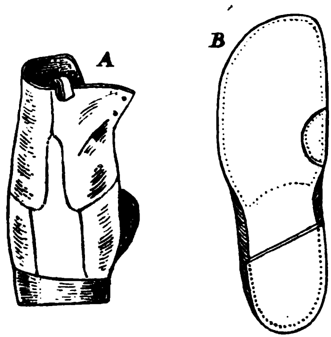


FIG. 28.—*A* and *B*, boot with straight heel elongated and raised ⅛ in. on inner border, with small patch to thicken inner side of sole. (Jones.)

sole rigidly against a flat foot-piece, for if that be done every irregularity of bone will conduce to callosity when walking is resumed. It is necessary, therefore, at this stage to adjust a splint having an inside arch padded to conform to the natural shape of the foot. Eversion of the foot should be guarded against, and the hollow of the arch should, when possible, be emphasized. Later, the heel of the boot should be raised on the inner side to obviate ever-

sion, and, if the metartarsals are involved, in order to allow of early walking a bar should be placed across the sole of of the boot behind the tread (Figs. 27 and 28). Light duty can then be undertaken at a much earlier date.

FLAIL-JOINTS.

In answer to the question "What should be done with flail-joints?" I would say, "Secure by operation an ankylosis in the most useful position." The only exception is in the case of the hip-joint, where by means of simple mechanism a very useful limb may be obtained in spite of the joint being flail.

CHAPTER VII.

THE SPINE: ITS EXAMINATION AND THE SIGNIFICANCE OF ITS ABNORMALITIES.

THAT serious departures from the normal in so important a part of the body as the spine constitute a definite bar to military efficiency is self-evident. As in the case with the foot, there are conditions of the spine which may have permitted an individual to exercise the functions of civil life without interference or with only occasional and unimportant disturbance, but which under the stresses of military service become of very serious import. The difficulty and often the impossibility of controlling the conditions and the amount of work to be exacted from the soldier need but to be faintly understood to make this apparent. However, again, just as in the case of the foot, there are conditions of the spine in which the presence of departures from normal appearances are deceptive to the uninformed, in that they may not be incompatible with strength and the ability to endure the severest tests of function. Indeed, such conditions are at times to be found in men who are successful athletes. On the other hand, there are conditions of the spine, particularly of its lowest segment, capable of producing practically complete disablement for military service, which are not superficially apparent, but which frequently call for the most careful examination in order to be properly understood. It sometimes requires judgment and training of high order to tell what a spine will do or be able to do under difficult conditions.

In the case of the spine, then, it is again necessary to examine with one of two objects in mind: (1) to determine whether the spine will be able to meet the severe demands of military service, and (2) to properly care for such disabilities of the spine as have developed under service; some of these will by such care result in return to active duty and others will have to be recognized as constituting just ground for discharge to the less exacting conditions of civil life.

THE NORMAL SPINE.

Particularly among military men is there a very good idea of the appearance of the normal spine so far as this is related to general carriage, and it is by them well known that much of the abnormal posture which is seen in civilians is simply due to lack of muscular vigor and a careless attitude of mind toward the importance of a correct bearing.

THE SURFACE FORM OF THE BACK.—The back of a normal individual should be symmetrical both in the surface form of the two halves of the body as well as regards the outline of the trunk. The waist triangle, which is made by the vertical hanging arm forming the base, the slope of the chest down to the waist and from the waist to the hip, forming the two sides, should be equal on the two sides of the trunk. This triangle is, of course, much less well defined in the male than in the female. Especially in the male, the muscular development of the back is slightly greater on the right side than on the left, except in left-handed persons.

THE ANTEROPOSTERIOR CURVES OF THE SPINE.—It is well understood that if the spine curves forward in the cervical and lumbar regions, backward in the dorsal and sacral regions, being capable of considerable variation in this regard within limits to be regarded as normal, there is usually but little difficulty in concluding that an individual has an amount of backward curve in the dorsal region to be regarded as abnormal and therefore justifying the term "round back."

Similarly we speak of persons as sway-backed or as having "hollow back," who present an increase of the forward curve in the lumbar region. For military purposes it is sufficient to say that variations of posture within wide limits are encountered in recruits which, by the training given them, are made to disappear entirely, so that they no longer constitute even cosmetic faults.

IDENTIFICATION OF VERTEBRÆ.—It is worth while to remember that the seventh cervical, known as the "vertebra prominens," is usually really less prominent than the first dorsal. The spine of the *fourth lumbar* vertebra is on a level with the highest points of the iliac crests, and this is the most generally useful point from which to identify any given vertebra, although the first dorsal is also often used for this purpose.

ANATOMICAL VARIATIONS.—It is to be borne in mind in connection with the above that anatomical variation is far from infrequent, both as regards the number of segments and as regards the symmetry of the individual vertebræ.

NORMAL LATERAL CURVE OF THE SPINE.—There is very commonly a slight curve of the spine to the right in the dorsal region in persons who are right-handed. With the exception of this the spine should be practically straight in the sense that a plumb-line dropped from the seventh cervical vertebra should coincide with the fold of the nates if the individual's limbs are of equal length and if he is standing with the feet close together; in this case, also, all of the spinous processes should be in this line, or very nearly so.

MOVEMENTS OF THE NORMAL SPINE.—There are four movements to the normal spine:

1. Forward bending or flexion.
2. Backward bending or extension.
3. Side bending or lateral bending.
4. Torsion or rotation. Properly speaking, this is not a movement of the spine but results from the combination of lateral bending and the normal anterior or posterior curve of the part.

1. *Forward Bending.*—In standing the spine should bend forward until the finger-tips touch the toes, or nearly so, without any flexion of the knee-joints; in sitting upon a plane surface, with the back of the knees touching the table or floor, the same thing should be done. When this is done the spinous processes should outline an unbroken curve almost approaching the segment of a circle.

2. *Backward Bending.*—Can be done sitting or standing and is accomplished almost entirely in the lumbar region, although the lowest part of the dorsal segment participates.

3. *Side Bending.*—Should be equally free to either side; it is accomplished chiefly in the dorsolumbar region.

4. *Torsion.*—Is accomplished chiefly in the dorsal segment and requires no special discussion in this place.

The cervical region is not included in the above because of the universality of its movements.

DEVIATIONS FROM THE NORMAL SURFACE FORM OF THE BACK.

Lack of symmetry of the two sides of the back usually means scoliosis or lateral curvature of the spine. This calls for careful examination unless of very slight degree. In postural scoliosis there is lateral deviation of the column of vertebræ, which disappears completely or nearly so in forward bending and in prone lying; there is little or no rotation deformity, and this also disappears in these positions. Postural scoliosis is not disqualifying unless of unusually high degree. In structural scoliosis, on the other hand, we have permanent deformity of the spine and chest; it is associated with definite changes in the form of the bones and therefore does not disappear in forward bending or prone lying, but becomes even more evident so far as rotation is concerned. It is not disqualifying unless found in high degree, so as to be apparent through the clothing, or unless it can be shown to have resulted from other disease, such as empyema or

infantile paralysis. Care should be taken not to overlook these causes for scoliosis, and when found note should be made of them. Severe structural scoliosis with marked distortion of the chest is disqualifying because it betokens a condition of decided muscular weakness.

DEVIATIONS FROM THE NORMAL CURVES OF THE BACK.

The anteroposterior curves of the back may be found to be increased or diminished. Such deviations from the normal are not to be regarded as of great importance by themselves unless of high degree; when of moderate degree their importance is to be appraised by the region which is affected and by the concomitant signs and symptoms, chief among which is stiffness due to muscle spasm in the affected region. Thus a diminution of the hollowness of the lumbar region is very often found as a personal characteristic and without disease in this part of the spine; it is, however, often found in tuberculous disease of this part of the spine, especially in the early stages and in young adults. In this case stiffness in lateral and forward bending is almost sure to be found. Flatness of the lumbar region is often seen in connection with relaxation or strain of the sacro-iliac joints. In this case also we shall have stiffness in forward bending and a positive hamstring phenomenon to guide us. (See below, Movements of the Hip.)

Slight irregularities in the line of the spinous processes and slight prominence of the tips of one or two spinous processes are often present as peculiarities of development in the individual; they have given rise to erroneous diagnoses of "subluxations" quite often; they are not to be regarded as abnormal, however, unless *accompanied by other objective signs* of disease or injury. Marked deviations are usually evidence of pathological processes, which should disqualify for service. This is especially true of the posterior projec-

tion of several spinous processes in the form of "angular curvature." In any case of doubt an x-ray examination should be obtained for diagnosis.

THE DORSAL CURVE.—An extreme degree of increase in the dorsal curve, resulting in very evident malposture and flattening of the chest, with stiffness of the spine in this position, is a factor of potential disability. It produces liability to strain when subjected to added weight-bearing and physical activity. In such degree as this it is disqualifying. Lesser degrees of this condition are not only remediable when unassociated with other abnormalities, but are apt to be corrected by the training of military life; they are accordingly not to be looked upon as disqualifying.

THE LUMBAR CURVE.—The lumbar curve may show an increase from the normal by: (*a*) an increase in the general depth of the curve, and (*b*) an increase in the angle of junction in the sacro-iliac region.

These conditions are of importance as factors of potential weakness, which are likely to be brought into prominence by the stress of added weight-bearing. A sharp angle of junction in the sacro-iliac region, associated with a sacrum placed more horizontally than the normal, is an element of greater weakness than an increase of the general lumbar concavity. When either of these conditions is present in a moderate degree, and *unattended by clinical symptoms of strain*, it is not disabling. When associated with evidence of strain and with referred pain or when present in very marked degree the condition should be considered as disqualifying.

ABNORMALITY IN THE MOVEMENTS OF THE SPINE.

There may be limitation of the normal movement of the spine throughout its whole extent, or the limitation may be confined to a particular segment. The limitation may be in

one direction only, or in all directions. Marked limitation of movement in any part of the spine calls for careful examination; it is very likely to be the indication of a disqualifying condition.

Rigidity of the spine may be caused by muscular spasm or it may be due to pathological changes in the vertebræ and associated structures of either inflammatory or destructive character. Localized stiffness in any one segment of the spine, even though slight, is to be regarded as of more significance than a general stiffness of the whole spine. Any case of stiffness of the spine, particularly if attended with muscular spasm, should be examined with great care to determine its cause. It may be due merely to strain of the back (most frequently seen in the lumbar and lumbosacral regions), and in this case it is to be regarded as a temporary condition and not as a disqualification unless when associated with some abnormal structural condition. Such conditions are sometimes of congenital character, and in this event may be shown by the *x*-ray to consist of anatomical variations of a symmetrical character. Such variations are not to be considered as disqualifying, however, in the absence of objective and subjective signs and symptoms.

Rigidity of the spine due to pathological processes, such as arthritis of infectious or toxic nature, tuberculous disease, or resulting from *severe* trauma, should be regarded as disqualifying. This is also true even if the process itself is no longer active, but has left behind enough evidence of its former physical existence to make it recognizable.

MOVEMENTS OF THE HIP AS AFFECTED BY THE SPINE.

Hyperextension of the hip-joint would normally be possible to about 10 degrees; that is, when the individual lies prone on a plane surface it should be possible to bring the thigh back so that it will make an angle of 10 degrees with the

table. A considerable diminution of this motion indicates spasm of the psoas muscle and may be brought into connection with disease of the lower spine or even the sacro-iliac joint (most often tuberculous). It is of special importance in this connection if the other movements of the hip-joint are unhindered.

Limitation of the flexion of the thigh on the trunk, *with the knee fully extended*, may be unilateral or bilateral; this is of important significance when due to spasm of the hamstring muscles (hamstring phenomenon), and especially if in making the test pain is thereby called forth in the region of the sacro-iliac joint.

THE SACRO-ILIAC ARTICULATIONS.

These joints may be the seat of disease, such as tuberculosis, or may be the seat of disability from traumatic strains of the supporting ligaments or conditions of relaxation in these ligaments.

Tuberculosis of the sacro-iliac joint, while not of frequent occurrence, is found sometimes in young adults, and in its earlier stages is apt to be vague in its clinical manifestations. These are likely to be present in the form of a slight limp with a list of the body away from the affected side, a positive hamstring phenomenon together with swelling and tenderness over the joint; sciatic pain is frequently observed. The x-ray examination will often determine the diagnosis with definiteness. This condition, of course, disqualifies for military service.

Strains of the sacro-iliac joints may be acute or chronic in varying degree. If more or less acute they are likely to be associated with a flattening of the lumbar segment of the spine, together with stiffness of this same part of the spine. There is usually a list of the trunk away from the affected side, except the condition be bilateral; this is often the case.

In acute cases the condition is usually of traumatic origin and is to be regarded as temporary and amenable to treatment. In cases of subacute or chronic character the condition should be considered as disqualifying. In all of these cases a positive hamstring phenomenon is likely to be found. Demonstrable motion may be found at the sacro-iliac joints under these conditions, and is always to be regarded as abnormal. It is determined, in the standing position, by grasping the ilia with both hands, the thumbs resting on the posterior iliac spines, while the thighs are flexed alternately *and fully* on the trunk. Marked demonstrable motion in these articulations, with pain, is disqualifying.

INJURIES TO THE SPINE.

It is important to be able to recognize what is the real gravity of an injury to the back. In the hurry of military action it will most often be necessary to satisfy one's self that the back has been injured, leaving a more careful examination for a later time. The patient should for the time being be handled as if the injury were grave, so as to avoid possible damage in moving him. Even before there has been opportunity to ascertain the exact degree of injury by means of an *x*-ray examination it is possible, as a rule, to tell with a fair certainty whether there has been serious injury to the spinal bones and joints or whether anything more than strain and contusion of the muscles and tendinous structures has occurred.

When all of the movements of the spine are limited by muscular action and the attempt to make them is attended by pain it is fair to presume that the injury is severe and probably involves the deeper structures. On the other hand, as Jones has pointed out, when only the muscles have been injured, the "patient will resent forward flexion because it puts tension on injured muscles and ligaments, while if the

surgeon places his hand on the back and asks the patient to lean back over it, passively, not actively, he will flex backward with comparative freedom. . . . It is very important to distinguish clearly between flexions which are passive and those which are active."

Position of Choice in Spinal Injuries.—When serious injury has befallen the spine, involving the bones and joints, the movement in flexion forward and to one side or the other is to be avoided as being fraught with danger of further damage. The position of choice is therefore one of slight dorsiflexion. When placed in bed a Bradford frame should be used and the patient laid upon the back; a pad or small pillow should be placed under the knees to prevent strain on the posterior ligaments and relax the hamstring muscles, and another under the lumbar spine (its lower edge must not extend below the crest of the ilium) to preserve the lumbar curve.

Fixation of Cervical Spine by Cotton Collar.—A most comfortable as well as efficient fixation dressing for the cervical region of the spine is the cotton wadding dressing of Schanz. It is best made with unabsorbent cotton wadding, preferably in the form of bandages five inches wide. The bandages should be about three-eighths inch thick when uncompressed. The patient's head being held in the desired position by an assistant, several turns of wadding are made around the neck, filling out the interval between the chin and the sternum. Over this two or three layers of gauze or calico bandage are wound under moderate tension. Then two or three layers of wadding and again several layers of bandage. The outer layers of bandage may be wound tighter as the dressing grows in thickness. The dressing should be made very thick so as to be level with the point of the chin in front. After twenty-four to forty-eight hours the dressing will be found to have become somewhat loose; more layers of wadding and bandage should be added without disturbing

the original dressing. While this dressing looks decidedly clumsy it is very agreeable to the patient and if kept firm enough is really a more efficient form of fixation for the cervical spine than the usual plaster dressing as applied to this region.

STRAPPING FOR SIMPLE BACK STRAIN.—Whereas rest in dorsal decubitus on the Bradford frame or on a firm mattress

FIG. 29.—Strapping of the back. Above, the vertical strapping as applied for strain of the dorsal or lumbodorsal region; below, the strapping as applied for strain of the sacro -iliac joints.

with a pad or small pillow under the lumbar spine will give the patient comfort, it is often possible to contribute still more to his ease, and in slighter cases even to permit him to move about, by properly strapping the back with adhesive plaster. When the dorsal or dorsolumbar segment are the

seat of strain, vertical strips may be applied as follows: The patient is placed on an unyielding surface, face down; two blankets made into a large roll are placed under the sternum, so as to throw the shoulders strongly backward. A strip of adhesive plaster, two and a half inches wide, is made to adhere to each side of the line of spinous processes, from a point on a level with the first dorsal vertebra to the middle of the lumbar hollow; these strips are secured by other strips, sixteen inches long by one inch wide, crossing the spine diagonally.

This dressing may be combined with the one described for the sacro-iliac joints if desirable.

Strapping for Strain of the Sacro-iliac Joints.—If it is believed that the sacro-iliac joints of one or both sides are the sole seat of injury it is important that the support should involve only the interval between the tips of the great trochanters below and the crests of the ilium above; further, the strapping had best not completely encircle the pelvis but be interrupted in front. This is because the sacro-iliac joints are slanted from above and outward, downward and inward in the vertical plane; from in front and outward, backward and inward, in the horizontal plane. In other words, like a letter V with the opening upward, in the vertical plane; like the letter V with the opening forward, in the horizontal plane. If the crests of the ilia are included in the dressing the tendency is for the sacro-iliac joints to be spread open below; if the strapping be applied in a complete circle the tendency is for the joints to spread at the back.

For the dressing three or four strips of adhesive plaster, two and a half inches wide are required. They should be long enough when applied under strong tension to reach from just posterior to the anterosuperior spine of the one side, across the sacrum, to the same point on the other side. For the application the patient lies on the abdomen, the surgeon

standing preferably at the patient's right. The patient being rolled slightly toward his right side, the first strip is made to adhere at a point just posterior to the left anterosuperior spine, midway between the trochanter and the iliac crest; the patient rolls toward his left and the strip is passed under strong tension across the sacrum, tightly adhering, to the corresponding point on the right side of the pelvis. A second strip is now passed, overlapping one-third, below the first. A third strip is then passed, overlapping one-third, *above the first.* A fourth strip may then be passed for reinforcement, or in the case of an unusually wide interval between trochanter and crest. A felt pad may be placed over the sacrum to make pressure should it seem desirable. Likewise it may be desirable to place several horizontal straps across the lower lumbar spine, although this is not usually to be done.

CHAPTER VIII.

METHODS OF TREATMENT FOR DISABILITIES FOLLOWING NERVE INJURIES.[1]

THERE are few problems more urgently needing solution at the present time than those involved in the treatment of limbs disabled by injuries involving nerves. The conditions vary and are often very complex. The nerve may be irretrievably injured beyond all hope of suture; it may be entangled in cicatricial tissue; one or more of the muscles it supplies may have suffered grave lesions, varying from partial to complete destruction; the tendons or muscles themselves may be bound down by adhesions, or the joint or joints the muscles govern may be stiff, ankylosed, or held in a deformed position by a skin cicatrix; or more than one of these hampering conditions may be present. The simple condition, where the nerve or some of its fibers receive a clean severance, is exceptional.

If once these facts are realized it will require no argument to establish the proposition that certain orthopædic problems must be mastered in connection with the suture of nerves if proper restoration of motor function and of the normal efferent and afferent connection between muscle and the central nervous system is to be secured. In certain fortunate cases the conductivity of the nerve is restored and good muscular function may result. In other instances,

[1] This chapter is taken from "Notes on Military Orthopædics" by Col. Sir Robert Jones.

although the conductivity is restored, the function of the muscles and joint may not be regained because certain fundamental principles have been neglected. There are other cases in which the conducting power of the nerve is not properly restored, and yet others in which, owing to extensive destruction of the nerve, any attempt at suture would be futile. We must therefore be prepared with alternative methods in order to secure for the patient a satisfactory limb.

LATE SUTURE OF NERVES.

With regard, however, in the first place, to late suture of the nerve, certain general principles must be borne in mind. These are:

1. The correction of contractures of skin or muscle and all the anatomical constituents, from skin to bone, on the concave aspect—that is to say, on the side of the abnormal direction the contracture takes.

2. When possible the freeing of joints from all adhesions and the restoration of the mobility of the joint in all cases where ankylosis is threatened.

3. The maintenance of the paralyzed muscles in a position of relaxation throughout the period of recovery.

4. The practice of massage during the recovery, but without once allowing the relaxed muscles to be stretched.

In short, the principles and their application coincide with those I have so often emphasized in the treatment of poliomyelitis.[1]

1. Freeing the Muscles.—If the muscles are not freed from all mechanical obstructions to their action, they cannot respond to stimuli sent to them through the nerve,

[1] The Annual Oration, Medical Society, May 18, 1914, on "Infantile Paralysis: Its Early Treatment and the Surgical Means for the Alleviation of Deformities."

and therefore cannot in their turn send the answering afferent impulse which is necessary to bring the apparatus into proper working order. It is essential to dwell on this point, inasmuch as many operations are being performed while the muscles and joints are stiff. This stiffness is not due to the nerve injury, but to the consequences of trauma and sepsis affecting the muscles, tendons, bloodvessels, nerves, and ligaments about the joint. When we realize how anemic an unused muscle becomes, we shall not delay in giving help to prepare it for the reception of nerve impulses.

2. Mobility of Joint.—Where the joint is threatened with ankylosis every effort should be made to restore its function. Operation on the nerves is doomed to failure if these fundamental principles be disregarded.

3. Relaxation of Muscles.—The importance of keeping the partially paralyzed and overstretched muscles in relaxation during treatment has been so forcibly brought home in ordinary civil practice in the treatment of residual paralyses after poliomyelitis, lead palsy, injuries of the brachial plexus and of isolated nerves, that it should be scarcely necessary for me again to call attention to it. Nevertheless, visits to wards prove that this elementary orthopædic measure is too frequently entirely omitted by surgeons who have performed suture of injured nerves. Thus we find men who have had the musculospiral sutured allowed to walk about with the hand dangling in palmar flexion instead of its being kept continuously in dorsiflexion! By letting the hand hang in palmar flexion the muscles supplied by the sutured musculospiral, which can only recover if kept relaxed, are allowed to become stretched. The result is that the fingers and hand do not regain, can hardly be expected to regain, full normal function. A similar grave error is often perpetrated in the case of the external popliteal nerve, with the same disappointing result in the foot. Frequently I have noticed that the foot of a

patient whose popliteal nerve has been sutured is allowed to remain in an equinus position! Sometimes, indeed, the operation is even performed while the tendo Achillis is contracted. Were it not so frequently happening I should feel ashamed to refer to this matter, but as it is happening I again urge surgeons who suture nerves to insist that the affected muscles be kept in complete relaxation until power returns. The most skilful operation performed on the most suitable case will prove a fiasco unless the affected muscles are continuously kept relaxed until recovery takes place.

Not only will it be found in some cases that no provision is made for the muscle to be in the most favorable condition to respond to the earliest motor impulses which come through the block in the nerve, but, further, the mechanical condition of the muscle as to function seems to be entirely neglected, and suture of the nerve is performed when the paralyzed muscle or the joint on which it acts is immobilized by cicatricial adhesions. If restoration of function is to follow nerve suture, the new axis-cylinders growing through a cicatrix must, of course, be enabled to establish some sort of normal relation as to function with the end-organs in muscle. If the muscle is mechanically disabled from making any response, it is absurd to hope for good functional result, even though the physiological processes of repair of the nerve be perfect. I desire to emphasize again the fundamental principle of procedure—namely, that the restoration of the mobility of joint and muscle must precede the operation of nerve suture. It is useless to attempt it otherwise.

4. Voluntary Use and Massage.—For precisely similar reasons, it is important that the patient should, as soon as possible, exercise the limb in normal movements. In the case of the lower limb this usually means the application of some apparatus designed to prevent strain on the recov-

ering muscles while the patient is permitted a moderately free physiological use of his limb. In order to make the foregoing observations more lucid to those who have not followed my writings, which are based on the late Mr. H. O. Thomas's theory of "muscle lengthening," I will briefly indicate their tenor.

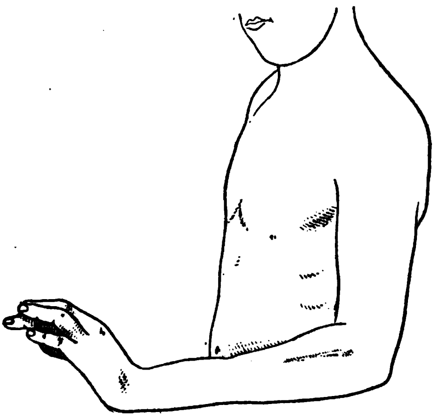


FIG. 30.—Showing action of dorsiflexing after transplantation of tendons. Captain McMurray's case. (Jones.)

It is well, in view of the enormous number of injuries to nerves occurring in this war, to emphasize the fact that principles applicable in poliomyelitis are applicable here. When speaking, some years ago, of the results of acute poliomyelitis, I pointed out that, though the disease might permanently destroy motor cells in the anterior horns of the gray matter, so rendering forever useless the muscles dependent upon them, unless nerve transplantation might at some later date come to their rescue, yet *complete* destruction was fortunately the rarer condition. The clinical

evidence afforded by rapid and complete recoveries from complete paralysis and the very many partial recoveries proved that the motor cells concerned had suffered from temporary injury and had not been destroyed. Something had happened to make the muscle incapable of responding to motor stimulus. Whether this was to be attributed to the absence of afferent muscle-sense stimulus, as seemed probable, or whether it was due to some other cause, it was clinically certain that the nerve cells became partially inactive, not extinct, and that with appropriate treatment of the muscle or group of muscles functional activity could be reinstated. When a muscle governed by a live cell,

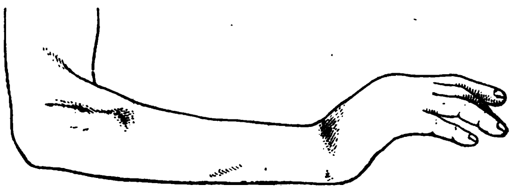


FIG. 31.—Illustrates a similar result in another of Captain McMurray's cases. (Jones.)

or rather a group of live cells, fails to act, the disability may be spoken of as functional. Of this disability the great outstanding cause is overstretching of muscle fibers. A surgeon must recognize the difference between a truly paralyzed muscle and a muscle which is overstretched, and must know how to distinguish the one condition from the other.

The first essential of treatment is that the muscle or muscular groups must be prevented from being overstretched. If the wrist is, for instance, allowed to remain flexed, the flexor muscles undergo adaptive shortening, and the extensors become overstretched and consequently placed at a

mechanical disadvantage. This point is well illustrated by dropped wrist from lead poisoning. The lesion here may be either in the cord or in the nerve trunks; in either case the muscles cease to be controlled by their nerve centers, and the patient goes about with his wrist flexed by gravity, and the extensor muscles become disabled by continuous overstretching. As the condition is usually bilateral, an interesting experiment to test my contention may be made, if the case be of some weeks' standing, by placing one of the paralyzed wrists on a splint to keep the hand dorsiflexed. It will be found that recovery will be much more rapid on the side on which the extensors are relieved from overstretching than on the other, neglected side. When a muscle is deprived of the natural motor stimuli, its condition from the point of view of function and nutrition is the same whether the absence of stimuli be due to inactivity of the central nerve cells or to interruption of the conducting paths along the peripheral nerves. Its motor function is suspended, its nutrition suffers, it becomes anemic, and it may easily be overstretched by gravity, by the unrestrained action of the opposing muscle, or by these two forces acting in combination. If the wrist and fingers are kept in extreme dorsiflexion, the extensor muscles, thus relieved of strain, undergo adaptive shortening, and soon begin to respond to the constant stream of tonic stimuli sent to them by efferent impulses; later they come under the higher control of the voluntary centers.

Another cause of persistence of functional disability is an unequal degree of recovery in opposing muscular groups.

Deflection of Body Weight.—A most potent factor for evil is what I have called the erroneous deflection of body weight, which, for physical reasons, operates chiefly in the lower limbs. If, for example, there be weakness in the tibial group and the patient be allowed to walk, the valgoid deformity will constantly increase, the tibial muscles

will be more and more stretched, adaptive contraction will affect the peronei, and structural alteration will ensue in the tarsal bone, terminating in a troublesome flat-foot. All these untoward results may be avoided by simple treatment on sound scientific principles; a little alteration of the boot which, by raising the inside of the heel of the boot, will deviate pressure from the inner to the outer side of the foot, may suffice. When we have to deal with a group of muscles in which the power is only slightly impaired, the muscular balance may be restored by overdeveloping the weaker group. If, for instance, the peronei are weak, but the foot can quite easily be placed in the everted position, then massage and exercises may reasonably be expected to succeed. But if the foot cannot be everted because of adaptive shortening of the tibial tendons, then massage and exercise of the peronei will be perfectly useless until such time as the deformity has been corrected and the overstretched muscles kept relaxed for a sufficient period to permit them to recover by interstitial shortening.

LATE RECOVERY OF MUSCLE POWER.

Before any operations are performed affecting the mobility of a joint, every use should be made of available muscle power. No surgeon should operate on these cases until he has fully satisfied himself whether or no it be possible to restore the apparently paralyzed muscle. Neglect of this precaution produces such a distressing occurrence as the unexpected recovery of muscles which were ignored because assumed to be paralyzed. For example, a patient was brought to me once with a partially ankylosed knee. The operation of arthrodesis had been performed with a view of bringing about bony ankylosis. As an arthrodesis the operation had failed, for the knee had a short range of movement. As an experiment, illustrating the principle we

are discussing, it was very successful, because the quadriceps was acting with considerable strength. Prolonged fixation had relieved the quadriceps from all strain, and restoration of function resulted. This case exemplifies the mistake of taking for granted that a muscle is paralyzed without first making quite certain that it is *really* paralyzed. It is only possible to make quite certain by relaxing the muscle, and thus putting it into the position most favorable to recovery, for a sufficient length of time. Electrical tests cannot be relied upon to give this information.

Treatment to Promote This.—The first stage of treatment is the correction of existing deformity. When deformity has been corrected the limb should be kept immovable until the ligaments, muscles, and even bone have become of normal length and shape. The continuity of treatment must be maintained or a relapse will result. This point is fundamental, and neglect to observe it spells failure, as the slightest stretching of a muscle on the point of recovery disables it again. All the good work may be thwarted by a single indiscretion. I cannot emphasize this point too strongly. For instance, let us take the case of a drop-wrist which has been placed in a splint designed to dorsiflex the hand at the wrist. The position must be constantly maintained. The hand must not be allowed to flex for a single moment until recovery has occurred. Even while the patient washes, the hand must be held dorsiflexed.

The clinical test of the recoverability of a muscle, therefore, depends on an experiment. Let it be kept for a prolonged period—for at least six months—in a position of relaxation. This test should always be made before condemning any muscle, no matter how long the period for which it may apparently have been paralyzed. When, therefore, one reads in text-books statements to the effect that we are to despair of the return of power after a certain length of time, we can quite well afford to ignore the advice

unless in addition to this time test there has been an uninterrupted muscular relaxation during that time.

These are views which I have without ceasing urged upon my professional brethren as applicable to infantile paralysis. They are equally applicable, with certain modifications, in the case of gunshot injuries. It is obvious that in infantile paralysis long mechanical treatment can do no harm. This is not so in the case of a soldier in whom a nerve has been injured. If suture is to give any promise of success there must be a limit to conservative methods, and in any case an exploration of the nerve is a harmless procedure.

TENDON TRANSPLANTATION IN GUNSHOT INJURIES OF NERVES.

In recommending tendon transplantation in gunshot injuries I have profited by the experience gained in anterior poliomyelitis. I have frequently performed tendon transplantation with success in the adult in cases in which isolated nerves have been destroyed. Similarly, unrecorded cases have been operated upon by my friends Mr. Thelwall Thomas and Mr. Bickersteth. At the Military Orthopædic Hospital, Liverpool, my colleague, Captain McMurray, has at the moment of writing three successful cases in which transplantation has been done for musculospiral paralysis. As previously indicated, the object of a transplantation is to improve or restore muscular balance. It is not justified unless it improves function. There is little satisfaction to a patient if the transplanted muscle merely responds to faradism, or even makes a feeble movement by the effort of the will. It must be, or give the promise of becoming, a substitute for the muscle it supplants, and it can only be judged by its ultimate usefulness.

A tendon may be transplanted in order to restore the balance between opposing groups of muscles by helping

a redistribution of power, or its attachment may be slightly altered to prevent deformity.

Recognizing that the principles involved in tendon transplantation are the same in both conditions, I will now briefly describe certain transplantation operations I recommend for various injuries.

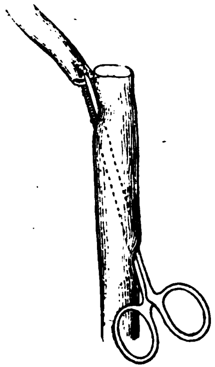


FIG. 32.—Showing the tendon which is to be transplanted about to be passed through a tunnel in the acting tendon. The tunnel is being dilated to receive the transplanted tendon. (Jones.)

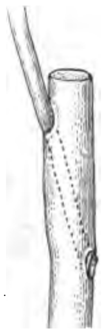


FIG. 33. — Transplant in position. The angulation is dealt with as shown in Fig. 32. (Jones.)

FIG. 34.—In order to overcome angulation a slit is made in the upper part of the receiving tendon, which is then wrapped round the transplanted tendon. (Jones.)

As a preliminary I give here a series of diagrams, Figs. 31, 32, 33, 34, 35, 36, 37 and 38, illustrating methods of transplantation of tendon into tendon, applicable under various anatomical conditions.

In the first part of this chapter I considered some general

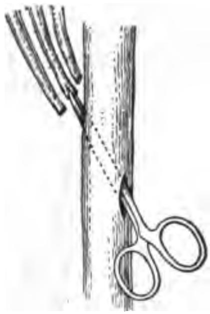


FIG. 35. — Tendons about to be pulled through another before suturing. (Jones.)

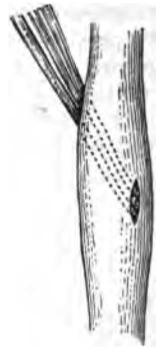


FIG. 36.—The divided ends of three tendons passed through another tendon in its course. (Jones.)

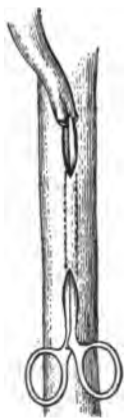


FIG. 37.—Showing transplanted tendon about to be passed along a tunnel in the receiving (active) tendon. (Jones.)

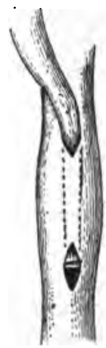


FIG. 38. — Tendon passed along course of active tendon. (Jones.)

principles which should guide the surgeon in the treatment of limbs disabled by injuries involving nerves. I pointed out the importance of giving the muscles ample time and opportunity to recover by keeping them in a relaxed position for a sufficiently long period, and I began the discussion of tendon transplantation as an alternative

FIG. 39.—Three tendons passed through another tendon, which has been split to receive them. (Jones.)

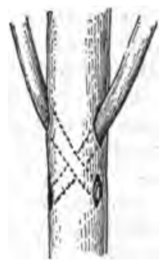


FIG. 40.—Tendons inserted into either side of active tendon. (Jones.)

method of treatment where nerve suture was not possible. I now propose to consider the transplantation operations my experience leads me to recommend in various injuries.

UPPER LIMB.

IRREPARABLE INJURY OF MUSCULOSPIRAL NERVE.—In cases of musculospiral injury the deformity is a dropped wrist, with loss of the power of extending the fingers. The uncontrolled action of the flexor group causes the fingers to curl into the palm, and the hand to become useless.

In such a case:

(*a*) The flexor carpi radialis and the flexor carpi ulnaris can be transplanted into the paralyzed extensor of thumb and fingers; and

(*b*) In addition the pronator radii teres may be affixed to the two radial extensors.

TRANSPLANTATION OF PRONATOR RADII TERES AND THE RADIAL AND ULNAR FLEXORS IN MUSCULOSPIRAL PARALYSIS.—I would recommend for this condition of musculospiral paralysis the double operation (*a*) and (*b*), and I will briefly indicate the method of its performance.

With the forearm midway between pronation and supination, an incision is made along the radial border of the forearm in its middle third. Under cover of the tendon of the supinator longus the pronator radii teres will be found where it becomes inserted into the outer border of the radius. From this it is detached, and is then inserted into the tendons of the extensor carpi radialis longus and brevis, which lie closely applied to it on the dorsal surface.

A horseshoe incision, with the convexity resting on the back of the carpus, with the two straight sides extending along the radial and ulnar borders, is now made. Through the lateral aspects of this incision the tendons of the carpi ulnaris and radialis are identified, and are detached from their insertion as near the carpus as possible.

The tendons are brought round the ulna and radius respectively in very slanting fashion, and are then attached to the extensors of the fingers and thumb, the carpi ulnaris being attached to the tendons of the three inner fingers and the flexor carpi radialis to those of the thumb and index finger. The method of fixation should be neat and workman-like.

INJURY TO MEDIAN AND ULNAR NERVES.—In the case of great damage to the median and ulnar nerves, operations on tendons alternative to those on the nerves will be very

rarely required as compared with those on the external popliteal and the musculospiral, for the reason that by means of flexion of the elbow a gap of two or three inches in the median may be closed up; by flexing the elbow and displacing the ulnar to the front a similar space in this nerve can be obliterated. End-to-end suture, therefore, is much more easily secured in these two nerves than in the case of the musculospiral and external popliteal.

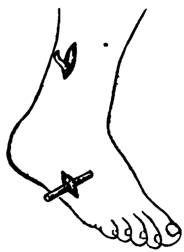


FIG. 41.—Tendon of peroneus longus divided in its course, and identified at the outer border of the foot. (Jones.)

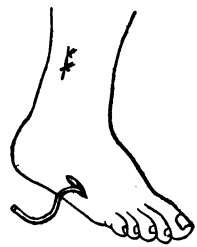


FIG. 42.—Tendon of peroneus longus drawn out through the lower incision. (Jones.)

In cases of complete and irreparable paralysis of the muscles supplied by the median nerve the only active muscles on the flexor aspect of the forearm are the flexor carpi ulnaris and the inner half of the flexor profundus digitorum.

TRANSPLANTATION OF TENDONS IN MEDIAN PARALYSIS.—(*a*) The outer tendons of the flexor profundus are inserted into the inner tendons of the same muscle.

(*b*) The tendons of the flexor sublimis are inserted into the tendon of the flexor carpi ulnaris. The extensor carpi radialis longior is attached to the flexor longus pollicis.

Method.—A curved incision is made convex downward with the apex just above the anterior annular ligament of the wrist. After retracting the flexor sublimis tendons, the outer two tendons of the flexor profundus are inserted into the two active inner tendons of the same muscle. The flexor ulnaris is then divided close to its insertion, and between the two portions of its split end the tendons of the flexor sublimis to the four fingers are inserted. The tendon of the extensor carpi radialis longior is now found at the outer border of the incision, and after division is inserted into the tendon of the flexor longus pollicis round the outer border of the radius.

TRANSPLANTATION IN COMPLETE PARALYSIS OF THE ULNAR NERVE.—The two inner tendons of the flexor profundus are attached to the two outer.

The palmaris longus is inserted into the tendon of the flexor carpi ulnaris.

After-treatment.—After operations for musculospiral paralysis the hand should be kept dorsiflexed until recovery of the muscle is complete. When the grafted muscles are acting sufficiently well and strongly to lift the hands and fingers, the time will have come for gradual training in coördination and balanced movement. Even after the patient has learned to use his hand, it is still necessary that he should continue to wear a dorsiflexion splint at night to prevent contractures of the flexors during sleep.

LOWER LIMB.

PARALYSIS OF ANTERIOR CRURAL NERVE.—Transplant the sartorius and biceps into the patella. An alternative measure would be the application of a knee cage with an extension spring to take the place of the paralyzed quadriceps. This should be worn permanently.

PARALYSIS OF MUSCLES SUPPLIED BY EXTERNAL POPLITEAL NERVE.—The anterior group of muscles and the

peronei are paralyzed. The deformity is a dropped foot with varus due to gravity and the uncontrolled action of the muscles attached to the tendo Achillis and of the tibialis posticus.

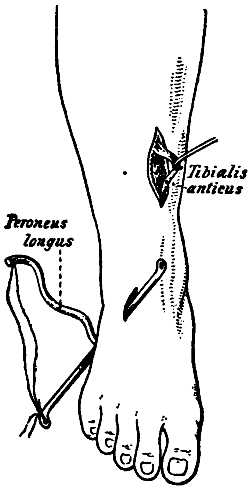


FIG. 43.—Tendon of peroneus longus about to be drawn through the incision opposite the annular ligament under which it has to pass. (Jones.)

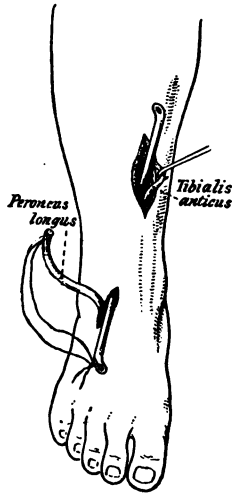


FIG. 44.—Tendon of peroneus longus about to be drawn under the annular ligament to be inserted in the tibia. (Jones.)

TENDON TRANSPLANTATION.—There is not much scope for effective tendon transplantation in this injury, except in cases in which only particular branches of the nerve have been picked out. For instance, an injury paralyzing the two peronei muscles, but leaving the anterior tibial nerve intact, would result in a deformity consisting chiefly of inversion of the foot at the midtarsal joint—that is, pes

varus. In such cases transplantation of the insertion of the tibialis anticus into the dorsum of the cuboid or into the base of the fifth metatarsal replaces the loss of the evertors and restores the balance of the foot.

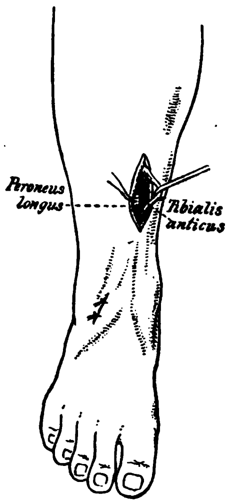


FIG. 45.—Tendon of tibialis anticus being drawn taut, the foot being kept at right angles; tendon is then cut and passed through a tunnel in the tibia. The tendon of the peroneus longus is shown drawn up through the same opening. (Jones.)

TENDON FIXATION.—In cases of more extensive paralysis there is not sufficient muscle power remaining for it to be effectually distributed; there is, so to say, not enough power to go round. Tendon fixation is then the best operative procedure, for it establishes a firm barrier against drop-foot, and yet allows useful mobility. Tilanus, of Holland, suggested tendon fixation for certain types of flail-foot,

many years ago, and I am hoping that it will prove increasingly useful in military surgery.

The object of tendon fixation is to utilize the tendons of completely paralyzed muscles as accessory ligaments to

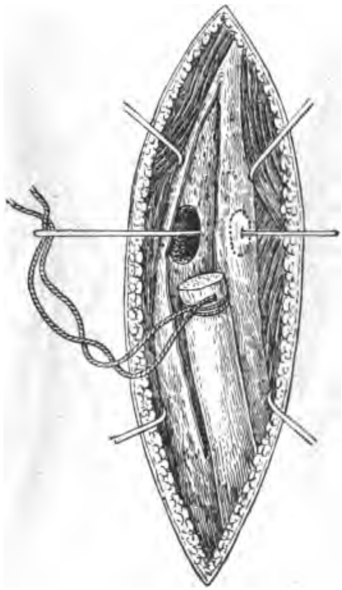


FIG. 46.—Tendon of peroneus longus about to be drawn through the hole drilled in the tibia. (Jones.)

hold a paralyzed foot in a correct position. This can be brought about in an endless variety of ways, and will supply the ingenious surgeon with many interesting and useful problems for reflection. Personally, after many successful operations, I would recommend this method of treatment to

meet the disabilities of paralysis due to injury of the external popliteal.

TENDON FIXATION IN DROP-FOOT DUE TO INJURY OF THE EXTERNAL POPLITEAL NERVE.—Two small incisions are made along the course of the peroneus longus tendon. The

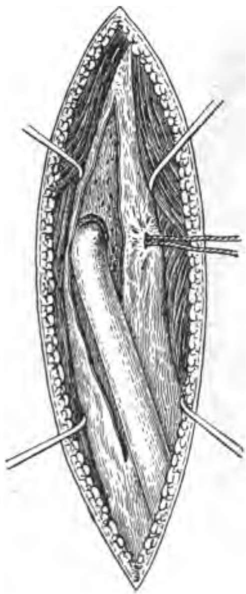


FIG. 47.—Tendon of peroneus longus drawn through the tibia. (Jones.)

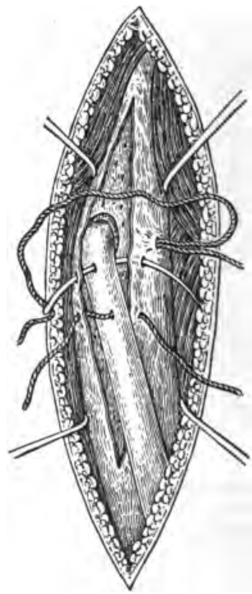


FIG. 48.—Tendon of peroneus longus about to be stitched to the periosteum of the tibia. (Jones.)

first is placed over the tendon, just before it turns around the outer border of the foot on to the sole, and the other about three or four inches above the tip of the external malleolus (Fig. 41).

The tendon is now divided through this upper incision and the lower freed position is then pulled out of its sheath

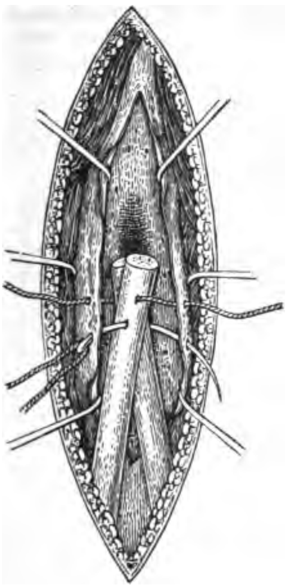


Fig. 49.—Tendon of peroneus longus and tibialis anticus inserted into a groove made on the surface of the tibia, showing the periosteum raised and drawn aside before being sewn in place. (Jones.)

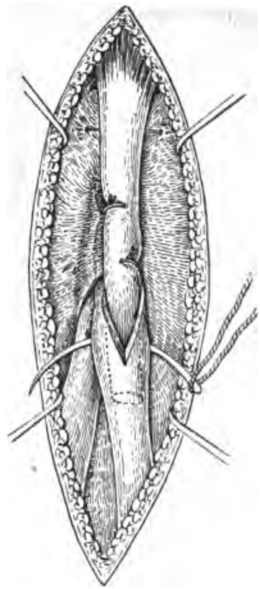


Fig. 50.—Lower divided portions of the tendons of the peroneus longus and tibialis anticus inserted into the tibia. The upper end of the tendon of the tibialis anticus sutured to the lower end below its insertion in the bone. (Jones.)

through the lower opening while its normal attachment to the sole remains undisturbed (Fig. 42).

An incision two or three inches above the tip of the external malleolus is made just externally to the anterior border of the tibia, and the divided lower portion of the peroneus longus tendon is passed up from the lower incision to this

FIG. 51.—Diagram to show the anatomy of the area concerned; the three parts of the annular ligament are shown, the tendon of the tibialis anticus is hooked inward, the tendon of the peroneus longus has been passed under the annular ligament and brought into contact with the tibia. (Jones.)

new one. In its new course the tendon should pass under the anterior annular ligament (Figs. 43 and 44), but if this cannot be done it may be passed in the deep fascial layer (Fig. 52).

The periosteum is now raised from the anterior aspect of the tibia and a deep groove is made in the bone; the tightly pulled tendon, whose outer surface has previously been roughened, is then laid in the groove and is retained in it by a small nail or it is fixed by strong catgut into fascia. The periosteum is then replaced over it (Figs. 49 and 50).

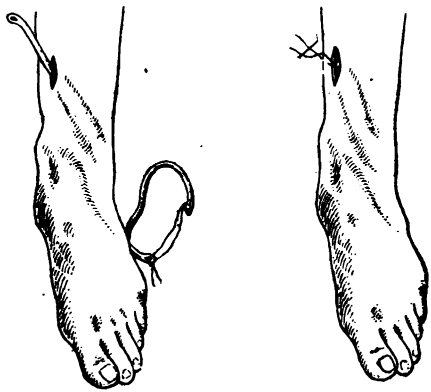


FIG. 52.—Alternative operation in which the tendon of the peroneus longus is pulled through the subcutaneous tissue without regard to the annular ligament. *A*, first stage. *B*, tendon of peroneus longus drawn upward and inward. (Jones.)

Another effective method of fixing the tendon is to bore a hole through the anterior border of the tibia and pull the tendon through (Figs. 46, 47 and 48). The free end can then be stitched to periosteum on the inner side of the tibia, or in some cases it may be more convenient to turn the tendon over the crest of the tibia and stitch it to the tendon before it enters the tunnel. Through this same incision

the tendon of the tibialis anticus (Fig. 45) is divided and the upper end of the lower portion inserted beneath the periosteum in front of the tibia, in a manner similar to that first described, by nailing, or through a hole bored in the substance of the bone, after the second method.

When this has been done, the cut end of the upper part of the tibialis anticus tendon is inserted into the lower part of the tendon distal to its insertion into the tibia (Fig. 50).

The peroneus brevis tendon may then be shortened and inserted into a gutter along the anterior surface of the external malleolus, by another short nail.

Another simple device consists in fixing the boot at right angles by means of a leather tongue which is fixed to the toe-cap, and a leather strap round the upper part of the boot just above the ankle.

Injury to Sciatic Trunk.—If the whole sciatic nerve has been divided high up in the thigh there is total loss of power below the knee and in certain muscles governing the knee-joint. In such cases the patient can walk quite well in a jointed calliper splint with a filling inside the boot to keep the foot at right angles. Another useful plan is to fit a jointed knee cage (Figs. 14 and 15) with a spring and a right-angled support for the ankle. This really means that we make the paralyzed distal part of the leg into a species of artificial limb, and this, in actual practice, has proved much better than any artificial limb that I have ever met with.

The idea of rushing to amputation of a limb merely because the sciatic nerve is destroyed, and therefore theoretically the nutrition of the foot must go wrong, is too horrible to be contemplated. Actual experience has proved that, in many cases, the errors of nutrition which ought in theory to occur do not occur, or, at worst, are not nearly so serious as might be expected.

CONCLUSION.

Surgeons will glean from what has been written that there are many ways in which the disabilities following nerve destruction can be met, and that hardly any case is bad enough to justify a counsel of despair. Our knowledge of what can be done in poliomyelitis will invite us to take a cheerful outlook in traumatic paralyses.

My intention in this chapter has been not merely to indicate ways in which the ground can be prepared for the operations of nerve suturing, or to point out the value of keeping a paralyzed muscle relaxed by opposing the force of gravitation, but to indicate the great and ever-increasing field of usefulness that is opened up by utilizing tendon, whether that of an active or a hopelessly paralyzed muscle, for the restoration of movement or the correction of deformity, thereby restoring to a greater or less extent the economic efficiency of an individual who would otherwise sink into the position of a non-productive and dependent member of the community.[1]

[1] *Editorial Comment.*—The experience of American orthopædic surgeons leads us to favor bone implantation of the transferred tendon when that is at all possible.

CHAPTER IX.

UNUNITED AND MALUNITED FRACTURES.

UNUNITED FRACTURES.

It should not usually be assumed that union of a fracture is not possible until at least three months have elapsed, and even a longer time should be allowed in persons in whom the bone fragments are markedly displaced or who have any constitutional disease which is known to act as a cause of delayed union, such as diabetes, syphilis, and acute systemic disease.

In this place it is not necessary to enter into a general discussion of the causes of non-union in fractures, but certain ones of particular importance in military work must be mentioned. These are:

1. Insufficient fixation due to frequent disturbance of the dressing. This may be frequently not preventable under conditions of warfare.

2. Too great constriction by dressings, resulting in insufficient blood supply and thereby delayed union.

3. Destruction of such an amount of bone that the apposition of bone ends is rendered difficult. When under such a condition traction is used in the treatment it may be a potent factor. In the treatment of fractures where much bone has been lost the greatest care must be taken in the use of traction lest it have this unfortunate result.

Treatment of Non-union.—When the diagnosis of non-union has been made, careful investigation should be insti-

tuted to ascertain the probable causes in order to determine whether union may not still be possible. If there be an apparent cause and the appropriate measures have not been thoroughly carried out, further trial may be made by conservative means. The method of fixation chosen should be one which will preserve alignment and length without constriction of the part. The local circulation may be improved by massage and passive congestion. It must be remembered that when union has been delayed the time which will be required for eventual union will be much longer in proportion to the period of delay. Patience is therefore required. In delayed union of fracture of the lower extremity the ambulatory treatment is sometimes successful.

When it has been once established that union is not going to take place, grafting[1] is today the operation of choice and is much to be preferred to wiring or the use of bone plates or devices of the same order.

MALUNION OF FRACTURES.

Since when these cases reach the orthopædic surgeon their causes are no longer preventable, these need not be discussed here.

MALUNITED FRACTURE WITH WEAK UNION.—"Weak union can be diagnosed almost with certainty even when ordinary manipulation fails to detect it. It is suggested by tenderness on pressure over the site of the old fracture, and confirmed by the additional sign of exuberant callus exudation. A malunited fracture of some months' duration, if accompanied by these two signs, can usually be corrected by forcible manipulation. This is a very important clinical fact to remember from the point of view of immediate or gradual correction." (Jones.)

[1] See precautions necessary in all operations, Chapter X.

Malunited Fractures with Firm Union.—These will require operative measures for their correction. The measures employed are the various types of osteotomy. The object of such operations may be: (1) To secure better alignment in the shafts of long bones and often at the same time to restore length when its loss has been due to overlapping; (2) to correct defective mechanical conditions in the neighborhood of joints, *e. g.*, Pott's fracture with eversion; (3) to improve joint motion.

1. In simple bowing of long bones, when the apposition is good, partial osteotomy with fracture may be done. If overriding of the bone ends is present but not too great, it may be possible to reproduce the line of the original fracture and so obtain an ideal reposition. If the overriding is marked, an oblique osteotomy should be done and additional length secured by traction, either by means of pulleys, or one of the special tables or apparatus designed for this purpose.

2. The restoration of proper mechanical conditions in the neighborhood of joints is sometimes simple but may require extensive bone operations to be effective. These operations for the most part are atypical and must be planned to meet the conditions as they are found. In Pott's fracture with eversion, sufficient correction can often be obtained by taking a wedge from the lower end of the tibia with its base directed inward and doing a simple osteotomy of the fibula.

3. The restoration of joint motion which is blocked by callus formation presents many interesting problems. For example, in the case of fracture at the lower end of the femur with extensive new bone formation which is interfering with the full power of extension, it sometimes seems unwise to attempt to remodel the joint because of the great extent of the operation required or because the general condition of the patient makes it desirable to simplify the

operation as much as possible. In such cases it may be advisable to do a simple osteotomy above the joint and straighten the leg, thus permitting the use of the amount of motion preserved in the most advantageous position. Similarly at the hip where, following injury or disease, the thigh has become fixed in adduction but with some motion still present in the joint, a subtrochanteric osteotomy (Gant) may be performed and thus the remaining motion utilized to the best advantage. The osteotomy should be a semi-circular one rather than the older simple osteotomy and it is to be performed by the open method.

CHAPTER X.

BONE GRAFTING.

THE severe infections associated with the wounds inflicted by shrapnel and other missiles, even when treated in the most skilful manner possible, naturally result in some instances in non-union, and in others in the destruction of considerable portions of the shafts of long bones with failure of regeneration due to loss of osteogenetic power. Such cases are proper subjects for bone grafting. *It must be remembered, however, that except in very rare instances bone grafting should not be attempted until at least six months after healing has* taken place, and that even when performed after as long a free interval as six to ten months infection of the most severe type has sometimes occurred (tetanus and gas infection). Such operations are not, therefore, to be lightly undertaken. Every means of determining the general and the local resistance should be used and it should be remembered that the loss of a little additional time is of far less moment than is the incurring of the slightest risk.

To determine the presence of latent infection, the scar is massaged, or in the case of a joint gentle manipulation, designed to *strain but not to tear adhesion*, are carried out, and the reaction if any, both local and general, is carefully observed in the next twenty-four hours; when in doubt the procedure may be repeated.

As precautionary measures in all operations in the region of old infections a dose of antitetanic serum is always given, and at the time of operation the old scar should be carefully

dissected away in the hope thereby of still further lessening the danger of lighting up the old process. Moreover, when it is at all possible bone grafting and similar operations should be performed in a room apart from that used for septic work and preferably by a staff which does not come in contact with septic cases.

FUNDAMENTAL PRINCIPLES.[1]—There are certain fundamental rules which should always be observed in the transplantation of all tissues. These rules must be adhered to as closely in the animal as in the vegetable kingdom. The science of grafting in the plant kingdom is centuries old. The most important rule of the process of grafting in the vegetable kingdom is the contacting of the alburnum of the scion or graft (which, in a way, corresponds to the periosteum) to the alburnum of the stock, or the part grafted. The contacting of the corresponding histological layers is not of such paramount importance in the grafting of bone as it is in vegetable life, but the importance of its observance is unquestionable.

The more closely these rules are adhered to, the greater will be the percentage of clinical successes. In the case of the bone transplant, nature is confronted with the following problems: (1) The rapid establishment of cellular nutrition and blood supply which is brought about by the extension of bloodvessels, and by the cellular assimilation of the serum in which the graft is immersed; (2) the union of the graft to the contacted bones or fragments of bones by osteogenesis on the part of the graft or recipient bone, or both; (3) through Wolff's law, which is the adaptation in form and increased strength of the graft to its mechanical requirements. If nature is to succeed in accomplishing this, it is quite essential that both the graft and the recipient bone should be favorable to cellular life and proliferation.

[1] NOTE.—The following description of the operative technic of the various procedures in bone-grafting is taken from Albee's *Bone-graft Surgery.*

The surgeon can do much in aiding nature by strict asepsis, by minimizing the trauma to all the tissues involved, by avoiding cellular death through either bruising or comminuting with hand tools, or by frictional heat from motor-driven instruments; by the avoidance of traumatism, thus guarding against necrosis of portions of the graft and lessening the danger of wound infection; by the proper protection and preservation of the graft bed and the graft itself from drying and possible infection; by so arranging his skin incision that it will not come directly over a superficially placed transplant, as this lessens the danger of skin necrosis and infection; by excising, if possible, extensive scars from the field of operation, as their poor blood supply is likely to interfere with the establishment of nutrition to the graft; by closely fitting and contacting bone surfaces which should, whenever possible, include the accurate coaptation of periosteum of graft to periosteum of recipient bone, of cortex to cortex, of endosteum to endosteum, and of marrow to marrow; by properly suturing muscle origins and insertions to the suitable mechanical locations on grafts which replace skeletal bones or portions of them (this is important if muscle control is to be reëstablished); by securing sufficient hemostasis in the graft bed by means of repeated applications of hot saline solutions, and by careful tying of bloodvessels. (A hematoma not only favors the development of infection but also interferes with the early nutrition of the transplant by the permeating serum; a small amount of blood clot, however, may be desirable.) By including in the graft the periosteum, endosteum, and marrow, which not only contain active osteogenetic elements but, on account of their loose structure, are more favorable than compact bone to a rapid reëstablishment of the blood supply with the recipient tissues of the graft bed, from whence nourishment rapidly reaches the compact part of the graft through the numerous bloodvessels passing from these enveloping membranes into

the compact bone. In other words, a bone graft consisting of all its elements approaches more closely a complete physiological unit—especially in reference to nutritional distribution—which is obviously an advantage.

The bone contact should be of generous extent and always with healthy vascular osteogenetic bone—the more unfavorable the bone, the greater should be the area of contact. Careful suturing as well as accurate coaptation should be secured when early use is to be made of the part, in order to obtain the benefits of functional irritation. In many instances where close contact and exact coaptation cannot be secured, early bony union may be accelerated by the interposition of numerous small grafts or fragments of bone. In early ununited fractures, it is the practice of the author to remove most of the fibrous union and substitute for it (after the inlay has been fixed in position) numerous bone chips between the ends of the fragments. These coalesce with each other and also with the graft and recipient fragments.

The modifications of the inlay technic meet practically all mechanical requirements; it is as applicable to fracture of the small bones of the forearm as of the tibia or femur; it controls the deformity of the foot, as well as of spinal caries; its inherent mechanics favor the fixation of the graft as well as the immobilization of the fragments into which it is inserted; its technic is not difficult, because it has to do with plane surfaces.

PRESERVATION OF THE BONE GRAFT.

The temporary immersion in normal salt solution is most satisfactory, and even this is usually not necessary, since, when possible, the graft bed should always be prepared prior to the removal of the graft, and the graft is immediately implanted in the prepared bed. This sequence of the opera-

tion is important, because (1) it assures an interval of time for the more perfect hemostasis in the graft bed; (2) it enables the surgeon by means of calipers, bone-wax model and flexible sterile pattern rod or flexible probe to obtain the exact size and contour of the graft required, thus

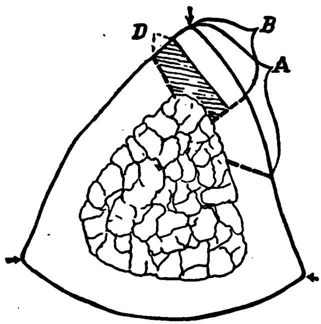
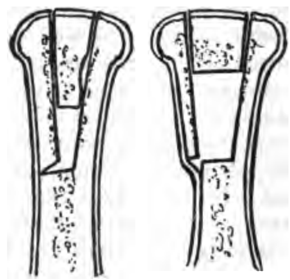


FIG. 53



A B

FIG. 54

FIG. 53.—Drawing of cross-section of tibia. *A* is spinal graft for an early case which has not become kyphotic. *B* is cross-section of graft which on account of the large size of the kyphosis is bent over it. *D* represents the multiple saw cuts on the marrow side. (Albee.)

FIG. 54.—*A* illustrates a cross-section of a spinous process split in half and fractured at its base. The deep, thin graft in cross-section has been removed from the crest of the tibia having its periosteum attached to two sides. The side in contact with the unbroken half of the spinous process is the saw cut or the medullary surface of the graft. *B* illustrates a cross-section of a spinous process which has been split and one-half has been set over to produce a gap sufficient to receive a broad graft removed from the antero-internal surface of the tibia having periosteum on one surface only; the medullary surface of the graft lies nearest the base of the spinous process in the gap. (Albee.)

avoiding unnecessary traumatization from holding forceps in reshaping a graft after its removal. Even in grafts where drill holes are necessary, it is far preferable to drill the graft before loosening it from the bone from which it is obtained.

A graft should always be used as soon after its removal as possible, but if it is necessary for any amount of time to elapse before it can be used, normal saline is not satisfactory as a preserving medium because of its evaporation and the consequent toxic effect. Sterile vaseline has proved a most satisfactory medium in which to keep the graft. It is not only perfectly non-toxic, but it is an efficient preventive of drying. The graft should either be immersed in a jar of vaseline or wrapped in gauze smeared with the same and placed in cold storage at a temperature of 4° or 5° C. Freezing is not desirable, as the resultant contraction and expansion damage the cellular content of the graft. Human grafts removed from the living as well as from a cadaver have been successfully kept by the author for forty-eight hours on different occasions. Emphasis should again, however, be laid upon the importance of using autogenous bone grafts whenever possible, as they are the most reliable; and as they are always used immediately, no preserving medium is necessary.

OPERATIVE TECHNIC OF THE SPINAL GRAFT.

PREPARATION OF GRAFT BED.—A sufficiently long skin incision is made, starting well above the diseased area and swerving to one side of the midline, and carried back to the midline well below the affected area, thus forming a semilunar skin flap with its border well away from this midline to avoid having the skin wound directly over the bone incisions and graft, thus fortifying the grafted area should any skin or suture infection take place.

Having dissected up this skin flap with its subcutaneous structure, the tips of the spinous processes, with the supraspinous ligaments, are exposed. As no important vessels are encountered in this region, hemorrhage is of slight consequence. If need be the bleeding-points may be clipped

and tied off, but a hot saline compress is usually sufficient to control any undue oozing and prevent large blood clots from forming. A certain amount of serous exudate and blood is considered advantageous to early fixation of the grafted area.

With a scalpel, the supraspinous ligament is split over the tips of the spinous processes, dividing them into equal halves; the interspinous ligaments are also split, care being exercised further not to sever any of the muscle or ligamentous attachments to these spinous processes. Then, with a broad, thin, sharp osteotome, one and one-half inches wide, the spinous processes are split to a depth, usually, of from one-third to two-thirds of an inch. One-half of each spinous process, always on the same side, is fractured completely at its base and set over a distance varying according to the thickness of the graft which is to be implanted. All bleeding-points are ligated or checked by hot saline compresses.

It necessarily rests with the operator to determine the size and thickness of the graft required, taking into consideration the segment of the spine to be grafted and the amount of strain the graft must endure. In general, the thickness of the graft should include the total thickness of the tibial cortex, including periosteum, endosteum, and marrow substance.

The graft bed now prepared presents on one side of the gutter the incised surfaces of the unbroken halves of the spinous processes, and in the intervals between these processes are the cut surfaces of the halves of the supraspinous and interspinous ligaments with their osseous attachments undisturbed. The opposite wall of this gutter is formed by the incised surfaces of the fractured halves of the spinous processes, with their portions of supra- and interspinous ligaments undisturbed, as in the opposite side of the gutter. This leaves the muscle and ligamentous attachments intact, save for the splitting, fracturing, and spread-

ing on one side of the spinous process halves with their attached ligaments. In other words, the anteroposterior diameter of the spinal column has not been diminished or weakened to any degree by the preparation of the graft bed. The full leverage of the spinous processes, as posterior arms of vertebral levers, has been preserved.

The length and shape of the required graft is determined by calipers and a flexible probe applied to the gutter-bed. The whole denuded field is packed with a hot saline compress until the next step is completed, namely, the removal of the graft from the tibia.

Removal of Graft.—With the patient still in the prone position on the operating table, the leg from which the graft is to be removed is raised from the table and flexed to an acute angle on the thigh. A skin incision is made along the antero-internal surface of the tibia, sufficiently long to allow a generous exposure of the tibia for the removal of the graft, and so placed that its closure will not bring the skin sutures over the bone cavity produced by the removal of the graft. The skin is dissected up from the periosteum, which is left undisturbed, and the muscles attached to the crest of the tibia are freed. The pattern of the required graft is outlined by incising the periosteum with a scalpel, using the molded probe as a pattern rod. The graft is best taken from the lower three-fourths of the antero-internal surface, as this portion of the tibia is usually sufficiently broad and furnishes a cortex denser and stronger than the upper portion of the bone.

If the graft is to be straight, it is best removed from the crest, wide enough to encroach upon the antero-internal surface, so as to furnish the width required. If the graft is to be molded for a moderate kyphosis, the pattern probe is so applied to the antero-internal surface of the tibia that the central or fulcrum portion of the curved graft includes the crest of the tibia and each end is cut

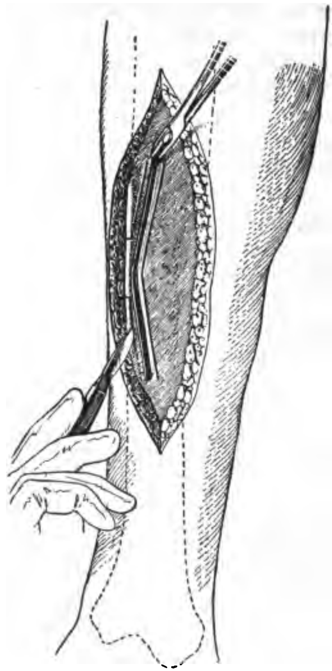


FIG. 55.—The flexible probe bent to conform to the spinal kyphosis and applied to the antero-internal surface of the tibia, held by a forceps while the shaped graft is being outlined in the periosteum by the scalpel prior to the removal by the motor single saw of the graft thus outlined. The center of the graft angle includes the crest of the tibia, thus strengthening its center. The ends of the graft include the cortical surface, the full thickness to the marrow cavity on the antero-internal surface. (Albee.)

obliquely across the antero-internal surface (see Fig. 55). The advantage of the graft thus obtained is that it includes

at its fulcrum portion the dense and thick cortical bone of the crest. This is important, because the strength of any lever is dependent upon the strength of its fulcrum portion.

After preparing the gutter-bed the spine is corrected by manual pressure on either side over the lateral masses, while the contour of the spine thus corrected is obtained by bending the probe into the clefts of the split spinous processes. The technic is carried out precisely as described above, except for the addition of the correction pressure while the kangaroo sutures are being placed to secure the graft in position.

The straight graft is obtained by cutting the tibial cortex through to the marrow cavity with the motor circular saw, following the periosteal outlines already made; this includes a saw-cut just to the outer side of the tibial crest and at a right angle to the one previously made on the antero-internal surface. This cut must be made the whole length of the graft, if a straight one; and, if a molded one, only to include the middle or fulcral portion. At either end beyond this central or crest portion the graft overlies the marrow cavity and the saw-cuts therefore need only to come on the antero-internal surface of the tibia.

At the ends of the graft saw-cuts are made with a very small motor saw to finish freeing the graft from the tibia. It is then loosened by a thin osteotome introduced into the longitudinal saw-cuts and pried free. The motor saw is not absolutely necessary for the removal of the graft, since a thin chisel or osteotome and a mallet serve the purpose, and certain operators have continued to remove the graft in this way. In adults the motor saw has a distinct advantage, as the bone is very dense and brittle, and if the chisel and mallet are used it requires the greatest care on the part of the operator to avoid cracking the graft or the remaining portion of the tibia. The method is not only slow but the constant blows of the mallet on the chisel traumatizes the

graft and does not allow its accurate molding. Pain in the leg has also been observed to be less since the motor outfit has been perfected for this use.

After the graft is freed it is seized by clamps and placed in the bed previously prepared for its reception, thus avoiding handling even with sterile gloved hands.

Fixation of the Graft in Position.—If the graft is a straight one it is held in place by first passing a strong kangaroo-tendon suture through one-half of the split supraspinous ligament at one side of the gutter; then the suture is passed up over the graft at its middle portion and through the other split half of the supraspinous ligament opposite. This suture is drawn taut and tied, thus approximating the two halves of the split supraspinous ligament over the graft at its central portion. The ends are next secured in like manner, always aiming to pass the suture deeply so as to get a firm hold upon the ligament and close to the spinous processes, either above or just below them. This insures a firmer contact of the graft to the separated halves of the split processes.

In certain instances it is advisable to place the suture either in the supraspinous ligament midway between the spinous processes or at a varying distance to the side of these processes, in order that the ligament may yield and the graft be completely covered. In the lumbar region, especially in adults, the supraspinous ligament may be so dense and tense that it is difficult on account of the required thickness of the graft to cover it satisfactorily unless the vertebral aponeurosis is incised on either side just external to the line of sutures. This allows a separation of the ligament sufficient to cover the graft.

Before the two ends of the graft are secured in position, it should be made certain that the graft reaches far enough below the diseased vertebræ to include two healthy spines; also the same should be made certain above the diseased

area. Emphasis is laid upon having the graft reach low enough because on account of the natural obliquity of the spinous processes in certain segments of the vertebral column, as in the thoracic region, the fact that the tips are well below their corresponding bodies may be somewhat misleading and the applied graft may be insufficient in not including the healthy vertebral spines below. Also, at this point in the fixation of the ends of the graft into position, the sharp posterior corners are removed by rongeur forceps, and these bone chips are placed about and under the graft ends before tying the graft end sutures. The graft ends should be sure to contact with spinous processes. The small fragments of bone so placed furnish added foci for bone proliferation, so as still more securely to amalgamate the graft ends to the contacted spinous processes. In other words, the smaller the graft the greater its comparative surface and the more active its bone-growing ability. It has been further demonstrated that small grafts, because of their size, obtain their nourishment more readily from their surrounding serum or blood, and a periosteal covering is not essential.

Kangaroo-tendon sutures at intervals of half an inch are now passed in similar manner as the sutures mentioned above, until the entire length of the graft is closed in and firmly secured in position.

If the graft is a curved one, cut from the surface of the tibia according to the pattern previously determined, the graft when placed in its bed must necessarily, from its curved shape, in order to fit the deformity, be placed edgewise, so that its periosteal surface lies to one side and its marrow surface to the other. The graft is so placed that the marrow or saw-cut surface shall contact with the side of the gutter formed by the unfractured halves of the spinous processes, and this periosteal surface consequently contacts with the opposite side of the gutter containing the fractured halves of the spines. The endosteal surface of the graft

with its attached marrow substance seems to be more active in its bone proliferative power than the periosteal surface. The curved graft is secured in position in the same manner as the straight graft.

The skin wound is closed in the usual way and sterile dressings are applied. Thick pads of gauze and cotton, varying in thickness according to the degree of the kyphosis, are placed on each side of the implanted graft. This is important in order to prevent pressure sores on the apex of the grafted kyphosis. The dressings and pads are then secured in place by broad strips of zinc oxide adhesive plaster. It is not safe, even with this dressing, to allow patients with prominent kyphosis to lie upon the back, but they must be restrained upon the side or obliquely on the back during the postoperative recumbent period.

THE IMMEDIATE POSTOPERATIVE TREATMENT.—The immediate postoperative care of these cases consists in recumbency upon the back on a fracture bed for five weeks in adult cases.

TECHNIC OF INLAY.

ARMAMENTARIUM NECESSARY FOR INLAY-GRAFT OPERATION.—(1) Hawley fracture table; (2) two Lambotte clamps; (3) Lowman or Berg clamp; (4) Albee electric-operating bone set, with twin rotary saws, burrs, drills, dowelling attachment, etc.; (5) periosteum elevator; (6) Lane bone spatula; (7) Chisels, osteotomes, and mallets; (8) Lion-jaw forceps.

TECHNIC OF INLAY-GRAFT OPERATION FOR FRACTURES (FRESH AND UNUNITED).—If traction is required, the patient is placed on a traction table, preferably the Hawley table. The perineal counter-traction post and patient are properly adjusted. The foot or hand is bandaged to the extremity traction plate. A generous skin incision is made overlying the point of fracture, and when possible should be made to the side of the intended site of the transplant.

The fascia and muscles overlying the point of fracture and the fragment ends are opened by scalpel and blunt dissection, and the region of the fracture well exposed.

If the fracture is an ununited one and the fragments are in good apposition, merely a part of the fibrous union is removed with a thin, sharp osteotome. In executing the inlay technic the periosseous structures are disturbed as little as possible and the relationship of the fragment ends left undisturbed if possible. This is important in minimizing the amount of local trauma. In this connection it is desirable to emphasize the pronounced inhibitory influence of severe trauma to cellular proliferation, and especially to osteogenesis. In no line of work is there greater danger of devitalizing trauma than in bone work, and this applies not only to the bone itself but to the surrounding soft tissues. A resulting infection of any of the involved tissue may interfere with a successful result.

Traumata may arise from the retraction of powerful muscles and their soft tissues—especially where too short an incision has been employed in the operative treatment of a fracture—from bone elevators or levers, bone clamps, the macerating and jarring effects of dull and blunt chisels, etc. Too great emphasis cannot be placed upon the importance of making the skin incision of sufficient length in all operative fracture work.

The periosteum is incised longitudinally and peeled back to either side in the form of flaps, exposing the bone which is to be removed for the purpose of forming a gutter in the fragment or fragments, as the case may be. If the inlay graft is to be obtained from the proximal fragment, the periosteum on this fragment is not disturbed, because it is always desirable that the graft include periosteum as well as endosteum and marrow substance. In fresh fractures the graft material can practically always be taken from the fragments themselves, as the osteogenetic function of this

bone has not become impaired. In most of our later cases of non-union the graft material has also been taken from the fragments, with uniform success. In such cases, however, the inlay fragment should always, when possible, be obtained from the upper fragment and slid downward into the distal fragment. This is important on account of the large amount of rarefaction which always appears in the distal fragment of a pseudo-arthrosis of long standing, and the relatively smaller amount of osteoporosis in the proximal fragment.

The author's inlay technic varies somewhat according to individual cases and requirements. The strength of the graft can be made to vary over wide limits. Its thickness will vary according to whether it is obtained from the upper or the lower portion of the antero-internal aspect of the tibia. Unless there is some reason to the contrary, it is better, as a rule, to obtain the graft from the lower part, where the bone cortex is thicker, stronger, and osteogenetically more active. The crest of the tibia at its lower third furnishes the strongest graft on account of its increased thickness of cortex and the fact that two cortical tables meet here.

In small bones, such as those of the forearm, the inlay is best held in place by kangaroo tendon, either placed in drill holes to the side of the groove or wrapped completely about the bone ends. In fresh fractures of large bones, such as the femur, where the marrow cavity has not become filled with new-formed bone and there is nothing to prevent the inlay from slipping into the marrow cavity, the graft and gutter-beds are made wider at their periphery than at the marrow side.

The fragment ends are freed and strong traction applied by means of the traction screw on a Hawley table. Lambotte clamps are placed on each fragment, and the bone is manipulated into apposition and adjusted so that the ends fit together perfectly. Loose fragments are replaced in their proper positions or are removed as seems wise. When the

ends are in apposition they are held so either by strong traction or by the use of a Lowman or Berg clamp placed on the fragments. If the fragment ends cannot be brought into apposition, it is not of serious moment when the inlay graft is used. It is not necessary to shorten the limb in order to get satisfactory apposition, as it would be if metal fixation plates were being used. The graft can safely be allowed to span a hiatus of any length.

The graft to be employed is usually removed from the fractured bone—generally the proximal fragment—and then slid into a goove one-half its length which has been prepared for it in the distal fragment. In a femur the sliding inlay should be about 5 or 6 inches long.

Technic for Inlay Graft with Wedge Cross-section.—The removal of both long and short grafts is started by making parallel cuts $\frac{1}{32}$ to $\frac{1}{16}$ inch deep, with the twin saws adjusted at a suitable distance apart, depending upon the size of graft and gutter to be formed. The purpose is to outline a graft of uniform width throughout its whole extent. These parallel saw-cuts are then continued through the cortex to the medullary cavity with the single motor saw held at such an angle as to cause the cuts to converge in approaching the medullary cavity, in order to prevent the graft when pressed tightly into position from slipping into the medullary cavity. The ends of the grafts are freed with transverse cuts made with either a very small motor saw or a narrow chisel. The thickness of the saw blade makes sufficient difference in the size of the graft and gutter to allow the inlay, when slid into position, to sink slightly below the borders of the gutter, thus furnishing a margin of the gutter sides above the graft into which holes are drilled obliquely to receive the autogenous dowel pegs.

The inlay, which has a wedge-shaped cross-section, is pressed tightly into position and held there firmly by either a Lowman or a Berg clamp while the holes are drilled and

the dowel pegs inserted. It may be necessary or wise to allow the drill to sink a fraction or its whole diameter into the edge of the graft. The pegs are obtained by splitting the short segment (removed from the distal fragment for the purpose of making the groove for the inlay) into two or three fragments, and pushing them through the author's motor lathe or dowelling instrument. Each of these dowels, which is long enough to make two or three fixation pegs, is driven lightly into the holes over the inlay, and while an assistant holds its distal end with a forceps the surgeon cuts the peg off with the small motor saw at the desired place. The remaining portion of the dowel is then used in like manner for additional pegs.

In ununited fractures of large bones, where the marrow cavity is filled with a bone plug which prevents the inlay from slipping into the medullary canal, and in all the smaller bones and in all individual cases where the mechanics are favorable, the twin motor saw alone is used in removing the inlay graft and preparing its gutter bed. In fractures of long bones where the difficulty of fixation is great, the inlay is held in place by the bone-graft pegs or heavy kangaroo tendon, or both, as seems best. The fragments are motor drilled on each side of the gutter, and the tendon is placed as indicated in Fig. 57. When the graft and its gutter-bed are formed wholly by the twin saws, the graft is just twice the thickness of a saw-cut narrower than its bed, which allows space for a heavy kangaroo tendon to be placed between the graft and gutter wall on each side.

In the case of small bones, such as the radius or ulna, the encircling of the fragments with the tendon is very efficacious in holding the insert firmly in its place. In severe comminuted fractures from gunshots or other causes, where there is a space to be spanned and the length of the limb is to be maintained by the inlay, it is best to tongue and groove the ends of the graft and bone cortex of gutter ends. The

groove should be in the end of the graft, and the tongue in the gutter ends. Any tendency to shortening of the limb by muscular pull, etc., causes the tongue-and-groove joints to become all the more firmly locked and is thus a sure preventive of shortening. The graft, however small, will

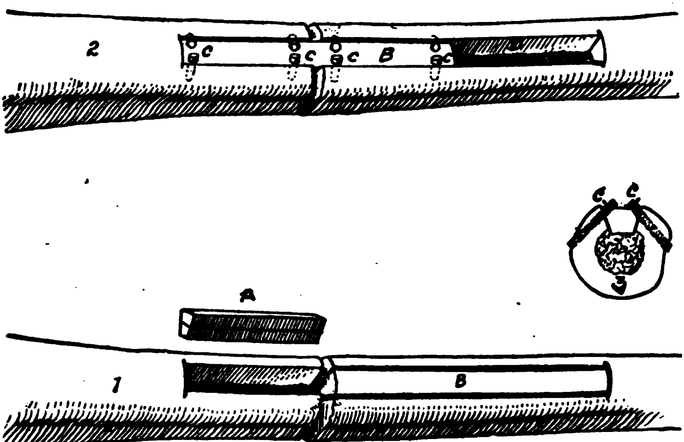


FIG. 56.—Illustrates the author's method of making use of the bone graft with wedge cross-section removed from the fractured fragments or from some other bone, as the tibia, in the treatment of fresh as well as ununited fractures of long bones. The smaller drawing (*3*) illustrates the graft dowel pegs in position holding the graft in place, and also shows the shape of the graft and gutter-bed on cross-section. *c*, dowel grafts in place. (Albee.)

in time hypertrophy, under the action of Wolff's law, and will become the size and strength of the bone whose substances it is supplying. The value of the graft in this type of cases cannot be overestimated.

An important point in the technic of bone grafting in its

application to all types of fractures is that the transplant should be of *sufficient length.* In the case of the intramedullary graft this might afford a great deal of difficulty, but with the inlay graft it is accomplished with ease. A graft six inches long can be inlaid as easily as one two inches in length.

In pseudarthrosis the inlay graft may vary from four to six inches in length—never less than four—according to the size of the bone fractured, the extent of osteogenetic impairment, or the amount of comminution. If the comminution

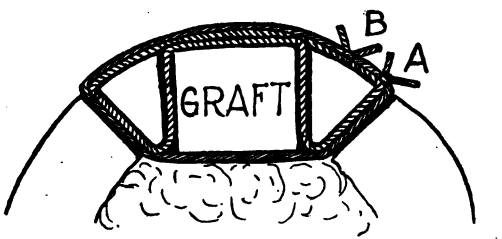


FIG. 57.—Diagram of the cross-section of a graft inlaid in a long bone, illustrating the manner of its fixation by kangaroo-tendon sutures passed through drill holes at either side of the gutter. Note that one suture passes through the drill holes and loops up over the graft and is tied; also note that a second suture passes under the graft and through the same drill holes, thus preventing the graft from falling into the medullary cavity. The gutter and graft in this instance are formed entirely by the twin saws. (Albee.)

is extensive, or if the fracture is of long standing, resulting in an unusual amount of osteoporosis in the fragment ends, it is preferable to obtain a transplant from the sound tibia, in which case the graft bed should be prepared first and packed with a saline compress in order to secure a sufficient hemostasis. Two parallel saw-cuts are made lengthwise in the fragment ends, extending through the complete thick-

ness of the cortex and into the marrow cavity. The distance between the motor twin saws is readily adjusted, according to the diameter of the bone and the point of fracture. The graft is then removed from the tibia, either from the crest or from the antero-internal surface, according to the strength required, with the twin saws adjusted as they were in making the gutter. In this way an accurate fit is assured.

The cuts should extend two or three inches into the end of each fragment, if the transplant is to be obtained elsewhere, as for instance from the tibia, and they should always extend far enough to reach well into active osteogenetic bone of each fragment. While the saws are cutting, they are constantly sprayed with saline solution, supplied either by squeezing a saline compress held over the saw or by an automatic spray attachment furnished by a sterile tube from a douche bag suspended over the table. This prevents excessive heating of the bone from the friction of the revolving saws.

The ends of the graft, as well as the strips of bone which, when removed, produce the gutter graft-beds, are cut for purpose of removal with a circular saw so small that it does not encroach into the walls of the gutter at the sides.

If the graft is to be obtained from one of the fragments, the twin-saw cuts are made twice the distance into that fragment. The strip of bone thus obtained is slid endwise into the gutter in the other fragment. The fragments are fixed by holding the inlay firmly in place by heavy kangaroo tendon or by bone-graft pegs, as the case indicates. The kangaroo tendon is passed through holes drilled by the motor in the cortex on either side of the gutter. The tendon —two strands in each fragment—is threaded through from one side of the gutter to the other and is then pulled up from the gutter in the form of loops, under which the inlay graft is forced into place, and then the kangaroo tendon

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is tied over it. The bone removed in the form of sawdust by the twin saws causes the graft to be just enough smaller than the gutter to allow room for the kangaroo tendon.

If the bone is large and the problem of mechanical fixation is more difficult, bone-graft pegs may be used exclusively or may be supplemented by kangaroo tendon. The bone-graft pegs are made by sawing longitudinally the piece of bone removed for the purpose of producing the gutter into two or three strips, which are turned into dowel pegs by pushing them through the motor lathe. The inlay graft is held in place by clamps while, with the electric drill, holes are drilled into the cortical bone of the sides of the gutter-bed. The pegs, which always fit accurately, on account of the drill being of the same diameter as the aperture of the dowel cutter, are forced into place by a few gentle blows with a mallet, and are cut off with a motor saw close down so that just enough projects to hold the inlay securely in place. The original dowel pegs are from two to three inches long, and will make from two to four fixation pegs. Numerous small fragments of bone are placed in between the ends of the fragments and about the graft at that point, just before closing the wound. These fragments should be of active osteogenetic bone, and are best made by a rongeur forceps.

By this technic foreign bodies are entirely avoided. The material used is either autogenous bone or absorbable material. The fit of the inlay and the pegs must be accurate by virtue of the motor-cutting tools employed.

This technic also allows the most ideal coaptation of the graft to its bed; that is, every graft should comprise four different tissues—namely, periosteum, compact bone, endosteum, and marrow substance; and this is the only technic which permits of the coaptation of each of these individual elements to those of the recipient bone.

FIXATION DRESSING.—The plaster-of-Paris splint applied over a thin padding of Shaker flannel or cotton wadding to protect the bony prominences has, in the hands of the author, proved to be by all means the most satisfactory. It can be readily split into a bivalvular splint by means of the author's motor saw (a special saw being used for the purpose) or by the Stillé cutter. The splint can then be easily removed for necessary treatment, etc.

Other satisfactory splints are Stimson's molded plaster-of-Paris splints. Splints of tin or wood-plastic splints of felt, papier maché, celluloid, etc., have been used, but are greatly excelled by plaster-of-Paris ones for the usual fixation dressing.

As stated elsewhere, the limb should always be placed in such a position that displacing muscles are relaxed by approximating their insertion to as near their origin as is practicable. An illustration would be the flexion-abduction posture used in fractures at the lesser trochanter, for the purpose of relaxing the psoas magnus and short trochanter muscles which pull the upper fragment into that position.

AFTER-TREATMENT OF UNUNITED FRACTURES OF PSEUDARTHROSIS.—On account of the sluggish osteogenesis of the bony elements making up a pseudarthrosis, a support should be continued much longer than in case of fresh fractures. In the more desperate cases some support should be continued for three or four months, because the callus formation from the bone ends is slow at best and all the stress may be borne by the graft, which will hypertrophy sufficiently if in the meantime it is protected from breaking.

TECHNIC OF BONE GRAFT FOR FRACTURE OF FEMORAL NECK.

The patient should be placed upon some traction table (Hawley) which will allow, simultaneously, abduction and traction. The point of fracture is reached by an incision starting from a point a finger's breadth inside of the antero-

superior spine and curved downward three to five inches along the inner border of the sartorius. The inner border of the muscle is exposed and retracted outward. The tendon of the rectus femoris is also exposed and retracted outward. The iliopsoas muscle is next exposed and retracted inward. The point of fracture is exposed and all soft tissue is cleared from between the fractured ends, which are curetted and freshened.

The limb is now placed in abduction and sufficient traction applied to bring the fragments into good apposition as determined by both sight and palpation through the anterior wound. An incision two or three inches long is then made over and just below the great trochanter, which is exposed. With a small hand drill the proper direction for the motor drill is determined by trial, as shown by observation through both wounds. The drill hole should be situated in the center of the neck of both distal and proximal fragments, and parallel to the neck. The small hand drill may have to be reinserted in order to locate the proper tract for the motor drill. The motor drill should be ready by the operator for insertion into the tract of the hand drill as it is withdrawn by the assistant. The motor drill, which forms a hole three-eighths of an inch in diameter, is pushed through the distal fragment until the burr end of the drill appears between the fragments, as seen through the anterior wound. Just as the end of the drill is engaging the broken end of the proximal surface, a reading on the graduated drill shaft is taken at its entrance aperture in the great trochanter, so that by making additional readings it can be determined just how deep the capital fragment is being penetrated. By studying the röntgenogram, the length of this fragment can be very accurately determined, and hence the desired depth of the drill hole obtained. When the fracture has occurred near the head and is consequently short, the drill hole should extend close to the articular cartilage of the head.

The drill is disengaged from the motor and left in place, to avoid any possible displacement of the fragments while the tibial graft is being procured.

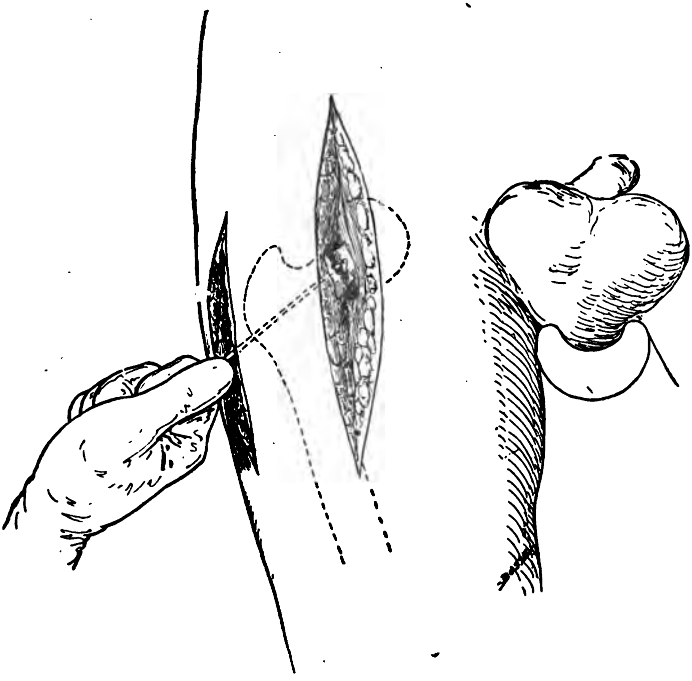

FIG. 58.—Drawing to illustrate author's method of determining with small hand drill the proper situation and direction for the motor drill. This hand drill is withdrawn as the motor drill is inserted. (Albee.)

The crest of the lower portion of the tibia is laid bare, and an area of the desired size and shape is mapped out in the

periosteum with a scalpel. The desired length of graft can be determined by the graduated scale on the motor drill. The cross-section of the graft should be just large enough to be shaped into the peg when the dowel shaper is used.

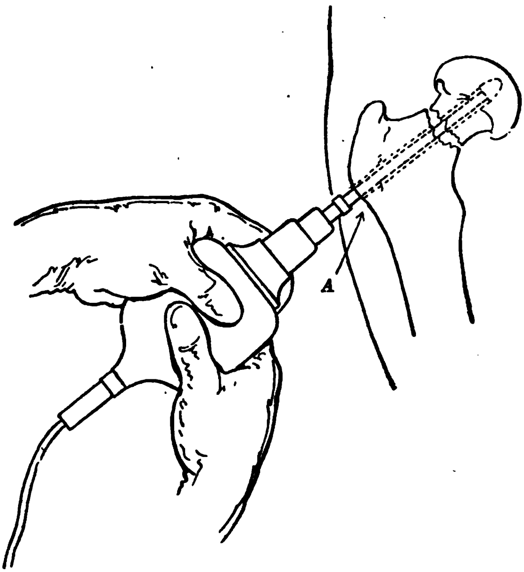

FIG. 59.—When the end of the burr has reached the space between the fragments and is ready to enter the capital fragment, a reading on the graduated shaft of the burr is taken at *A*; one is then able to tell by a study of the röntgenogram just how far the burr should penetrate this fragment. (Albee.)

When the graft peg is ready, the drill is withdrawn from the femur and the peg inserted. The fit must be accurate because the dowel cutter is the counterpart of the drill used.

This accuracy of fit is very important. Too tight a fit is undesirable because a pressure anemia of the surrounding cancellous bone would be produced. Too loose a fit or an irregular, inaccurate fit would not produce good fixation or favor an immediate bony union of graft to the host fragments.

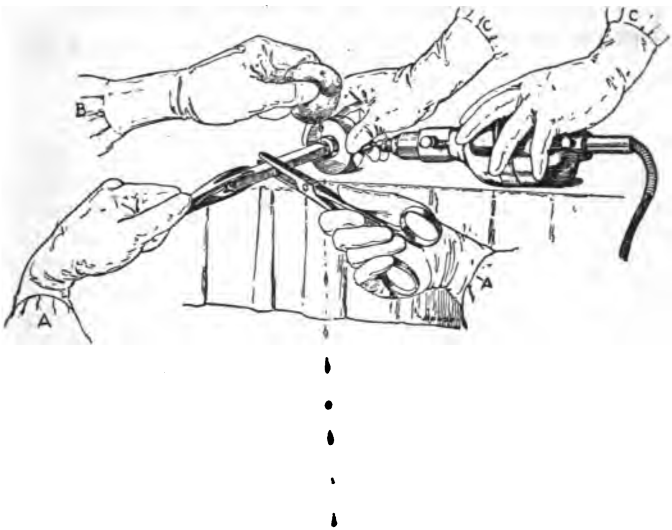

FIG. 60.—*A* is surgeon grasping and feeding the bone cuts. Author's motor-driven lathe. *B* is nurse supplying normal saline drip to avoid overheating the graft as fed. *C* illustrates assistant's manner of holding the motor and the lathe securely upon the edge of instrument table while the dowel is being shaped. (Albee.)

The deep fasciæ are approximated with interrupted sutures of No. 2 chromic catgut; the skin wound is closed with continuous suture of No. 1 chromic catgut.

The limb is put up in abduction (Whitman's position) in a plaster-of-Paris spica extending from the toes to the axilla. Three weeks after the operation windows are cut in the plaster and the wounds dressed. The dressing should be replaced with cotton for the purpose of restoring the tension of the plaster splint and retaining the fixation. The long spica should be continued for six weeks and followed by a short one for six weeks longer.

CHAPTER XI.

METHODS OF FIXATION: PLASTER-OF-PARIS DRESSINGS, SPLINTS AND OTHER APPARATUS.

THE value of the various methods of fixation is to be considered from three stand-points: (1) Efficiency, (2) simplicity, and (3) adaptability. In military surgery adaptability is to be estimated particularly with regard to (*a*) facility in transportation and (*b*) easy and painless access to wounds.

In our military service provision has been made for three methods of fixation: Plaster-of-Paris dressings, standard splints, and other splints, including both those of well-recognized pattern and improvised splints.

PLASTER-OF-PARIS DRESSINGS.

Whether one prefers plaster-of-Paris fixation to metal splints in general depends, of course, largely upon one's training. In America orthopædic surgeons have been taught to use both, and with few exceptions have no decided preference, being guided by the particular needs of the individual case. Naturally, however, plaster of Paris does not afford a suitable medium of fixation in the first zones; no attempt will be made to apply a cast until the patient has reached the hospital and even then it is usually not advisable to attempt a cast for the shoulder, trunk or hip unless a Hawley table or other similar apparatus is available. A disadvantage of plaster-of-Paris dressings is that they are likely to

become badly soiled by the discharge from the wounds, but by the use of proper precautions at the time of application this can usually be avoided and there is no doubt that for a large number of the cases a suitable cast will afford the most comfortable and efficient means of fixation. On account of the difficulty of the technic, the application of a cast should not be attempted by the inexperienced except under supervision.

Plaster fixation has proven most satisfactory for the transportation, over long distances, of cases of spinal injury and fracture of the femur.

Requirements of a Good Cast.—A satisfactory cast requires complete protection of the wound from coming in contact with the plaster, careful padding of bony prominences, smooth application of the plaster bandages (without wrinkles), exact molding to body contours, and just the right degree of tightness to ensure perfect fixation without constriction; all rough edges must be carefully smoothed before setting takes place. When the cast is carried over the fingers or toes, pledgets of cotton of proper size and thickness should be placed between the digits and removed after the plaster has hardened so as to avoid cramping them; before the plaster sets the cast should be flattened from before backward so as to ensure a flat position of the digits.

Provision for Windows in Casts (Osgood).—About the wounds are first wrapped sheets of oiled silk. As little padding as is safe is applied to the limb. Over this plaster is applied and after the first slight set the bridges with small pads of felt under their ends are incorporated and all the plaster about the wounds cut away, the oiled silk being turned back on both sides as cuffs. These bridges may be made of almost any kind of wire mesh or from pieces of flat iron. If flexible bridges with complicated curves are required, the wire mesh is chosen. If immediately rigid bridges are required or regular shapes can be used, then the flat iron is

preferred. The materials are cut in the proper lengths; if wire mesh is used, a plaster bandage is spread back and forth on the table a little longer than the metal, the layers being thoroughly rubbed in; this is then wrapped about the metal lengthwise and before it sets bent into the shape previously determined upon, the soft projecting ends of the plaster being spread out like little fans for greater security of incorporation; when flat iron is used, it is first bent to

FIG. 61.—Plaster with long arch and supporting rings attached to posterior bridge, for compound fracture of both bones of lower leg and multiple wounds of the anterior surface. (Osgood.)

shape and then covered by rolling the plaster bandage around it. The spans of these bridges are sometimes 25 to 30 cm., and in the lower leg these may often be applied as runners, lifting the leg from the bed and allowing very easy dressing and constant irrigation. If properly applied, such casts rarely have to be changed for two weeks, and then usually because they are too loose. If the drainage provided has been ample, there will rarely be an increase of swelling after the application of the plaster. Arrangement should always be made for the application of a tourniquet as a safeguard

in the event of a secondary hemorrhage. In all cases where this seems likely to occur, a tourniquet should be kept constantly in place above or beneath the plaster. It takes longer perhaps for the original application of such a cast than for some other forms of fixation, but it is believed that the saving of time and labor in dressings will much overbalance the increase in initial effort.

Combined Plaster and Metal Splints.—The use of metal strips may be still further developed so as to form a combined plaster and metal splint. For example, at the shoulder one may often secure the advantages of both methods by applying a cast over the chest and another over the forearm, and uniting the two by long metal strips or an improvised brace of wire, thus affording easy access to the entire humerus and at the same time securing the gain in comfort that the even pressure of the cast over the chest gives.

Plaster Ropes (Soutter).—Ropes of plaster are very useful for reinforcement and for making bridges of any desired shape. A moistened plaster bandage is spread back and forth on the table in the length desired, the layers are thoroughly rubbed in, and the whole piece then twisted into a roll, and again well rubbed; the ends may be spread out into little fans for greater security of incorporation.

Correction of Deformity by Means of Plaster Casts.—Deformity may be gradually corrected by applying a cast, cutting it properly and wedging it apart a little more each day. Care must be taken that harmful pressure is not produced either by using too great force or by an increase in pressure at some one point due to the change in position. To take a contracture of the knee-joint for an example, a pad of thick felt should be placed over the anterior surface of the thigh close to, but not pressing on, the upper edge of the patella, in order to protect the patella from all pressure, and other pads may be placed on the back of the upper thigh and the ankle, at the points where the pressure will be

exerted by the posterior edges of the cast when correction is begun; the cast is cut so as to leave a hinge of uncut plaster just over the first felt pad (and not over the patella); the opening on the back of the joint may then be wedged open gradually from day to day. If walking is not contra-indicated, a few turns of plaster bandage may be applied over the opening to make the cast firm and keep the wedge in place; this reinforcement is easily removed when further correction is desired.

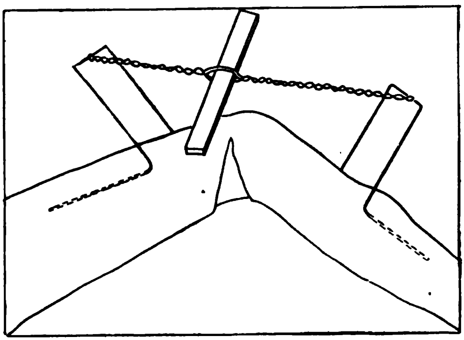

FIG. 62.—Method for correcting joint deformity by means of plaster dressing and improvised loops of heavy wire. (Freiberg.)

A more convenient method for applying the force is that used by Freiberg, which will be readily understood from the illustration. A very efficient apparatus of the combined plaster and metal splint type has been described by Turner.

PLASTIC SPLINTS.—These are particularly useful for fixation of the wrist and ankle. They are made in two ways: (1) By having the crinoline cut in the desired shape beforehand (Buchanan), and (2) by the use of the regular plaster bandage. In the first method the crinoline is cut in the

proper shape, plaster of Paris is incorporated in it, and six to eight layers placed one on top of the other; they are then rolled up like a bandage for soaking. In the second method a plaster bandage, after being soaked, is spread back and forth on the table in the length desired until sufficient thickness is obtained. Whichever way is used, the plaster with the layers well rubbed together is then placed between

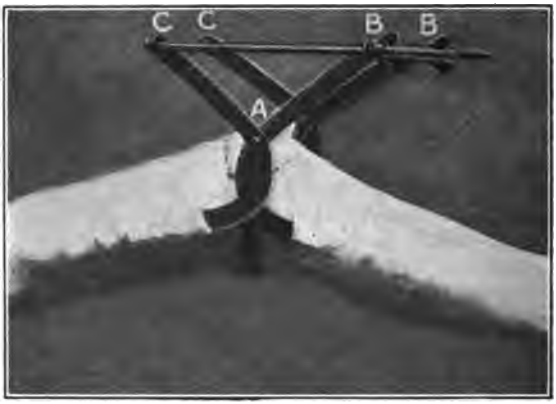

FIG. 63.—Turner's flexion apparatus for overcoming flexion of the knee.

layers of cotton or lintine before being applied to the limb, to which it is bandaged and the parts are held in proper position until setting has taken place.

PRECAUTIONS FOLLOWING APPLICATION.—While the first setting of the plaster occurs quickly, it does not become perfectly hard for some time. During this second period it is still susceptible of change in shape if sufficient pressure is made upon it. Constant pressure particularly must be carefully avoided. To cite a common example, when a cast has been applied over the foot and the patient is allowed to

lie with the weight resting on the heel, the plaster over the heel is frequently flattened, and when it becomes hard a painful and often dangerous pressure is exerted on the skin of the heel. Whenever there is pressure over a bony prominence, local ischemia in the tissue results with subsequent necrosis.

Casts may be applied too tightly or become too tight later from swelling. When casts are applied to the extremities, therefore, the circulation must be regularly inspected. It is possible to apply a cast so tightly over the whole part, or at one point only, that the circulation will be stopped entirely, in which case the part below the cast would appear white. Usually, however, casts become too tight later from swelling, and this is evidenced by congestion and swelling of the parts below. When too tight, the cast should be split and spread slightly.

Pain may be caused by constriction or local pressure on nerves or on bony prominences. The complaint of pain is always sufficient reason for a careful examination of the cast to see if it can be the cause of the trouble. It is usually easy to cut windows over suspicious points and by so doing much trouble is often avoided. Pressure on the external popliteal nerve sometimes occurs, and it is well in persons in whom the upper end of the fibula is very prominent to cut out the cast over this point.

STOCK SPLINTS.

For the immediate care of the wounded, splints afford the only feasible means of fixation; they will also usually be found most suitable for the entire management of the case.

In order to ensure uniformity of results in military work it is essential that methods of treatment be standardized. This implies first of all the limitation of the splints used to the smallest efficient number. Such a limitation is obviously difficult, particularly to a nation just entering the war.

Since the demands made upon us will be much the same as those already made upon the British Army, it seems wise for us to profit by their experience and begin, at least, largely with the types of splints they have developed, under the guidance of Col. Sir Robert Jones, after these several years of experiment and trial. These splints are of very simple design, are limited to as few types as possible, and are of rather rougher and heavier construction to meet the new conditions. Adjustable splints, advantageous as they are for ordinary use, have been found unsatisfactory. An added advantage of great value in choosing splints of the simplest design and material lies in the fact that they can be made by the convalescent soldiers and so serve as a useful means of industrial reëducation with the further gain in decreased expense. Moreover, when splints of this type of construction and finish become soiled, their renewal is a very simple matter: The felt covering is pulled off, the paint burnt off by passing the splint through the fire, thus at the same time sterilizing it, and it is then repainted and a new felt covering glued on, making it just as good as at first.

In hospitals a wider choice of splints will be possible and a change from the stocked types may be desirable to meet special conditions. In some instances these may be made by changing stock braces, but very many will be made in the orthopædic shop or by the orthopædic surgeon himself, using the recommended "equipment and materials if no regular orthopædic appliance shop is available."

A Board of Medical Officers in France was created (in accordance with Special Order No. 73, A. E. F., August 20, 1917) for the purpose of investigating and reporting upon the advisability of standardization of certain appliances to be used in the Medical Department.

The Board states that "The Medical Department has no desire to dictate the exact line of treatment which shall be employed in the base hospitals. It is the desire, on the contrary, to encourage ingenuity in devising better methods for the treatment of these bone and joint injuries,

which comprise so large a proportion of the battle casualties. The Board is convinced, however, after a careful review of existing methods in the armies of the Allies and enemies, and a personal experience in the active treatment of these lesions in the present war, that the simple apparatus recommended may be employed with entire satisfaction as to the end-results, and without any great degree of previous training."

The Board believes that "with the three types of wire-ring traction and counter-pressure fixation splints embodying the Thomas principle; the Jones 'cock-up' 'crab' wrist splint; the long interrupted Liston splint, with adjustable foot-piece; an anterior thigh and leg splint, Hodgen type; the Cabot posterior wire splint; the wire-ladder splint material; light splint wood; and plaster-of-Paris bandages and Bradford frames, treatment of all bone and joint battle casualties may be efficiently carried out at the Front, and if necessary in base hospitals."

"Holding this belief they have been influenced in thus restricting their recommendations to the above types of splints and splint material, by a consideration of the following advantages which their universal use would secure:

"1. Possibility of quick manufacture and ease of distribution, thereby making available large numbers of splints of unit construction.

"2. The combination of traction and fixation in the same apparatus, thereby favoring the comfort of the patient and avoiding the necessity of accessory adjustment.

"3. Universality of type and simplicity of mechanical principle, thereby ensuring quick familiarity with their uses and efficient application by the surgeon.

"The Board believes that it is the first duty of all surgeons to become familiar, by actual practice, in applying the splints to living models, with the methods herein recommended, the mechanical principles underlying these methods—namely, fixation and traction—and the details of the apparatus advised."

A description of those splints recommended which were not already described in the *Manual of Military Orthopædic Surgery* has been added in small type in the body of Chapter XI of this revised edition.

The splints chosen by the Board are indicated by a star.

* Bradford Frame.

Construction.—*Materials.*—Standard three-quarters-inch gas-pipe with elbows to match; for canvas covers, 12-ounce duck (Army standard), and half-inch grommets.

Size of Covers.—Twelve inches by thirty-four inches.

Inside Measurements of Frame.—Length six feet, width sixteen inches.

INDICATIONS FOR USE.—Spinal and pelvic fractures and other injuries requiring fixation in recumbency.

APPLICATION.—Covers must be taut, with five or six inches' separation to allow use of bed-pan; when necessary to support buttocks, opening may be closed in several ways: a piece of muslin or canvas, or a towel, may be drawn tightly around frame and pinned with safety-pins; a covered piece of tin or other sheet metal, with its ends bent over side bars, may be placed over opening and slipped down under thighs when pan is used. Place patient on frame so that anal

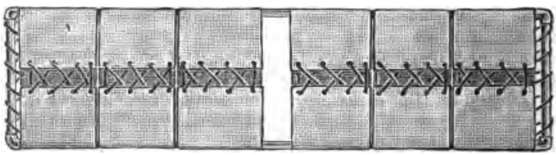

FIG. 64.—Bradford frame.

opening is opposite center of opening in canvas. Fix patient by a swathe encircling pelvis and frame and another just below shoulders; thighs may be fixed if indicated. Support spine, when indicated, by properly shaped pads.

CARE AND PRECAUTIONS.—Guard against sagging of buttocks into opening by keeping it as narrow as possible or by methods mentioned above. Unless contra-indicated a pad under knees to prevent strain on posterior ligaments and another under lumbar spine (its lower edge must not extend below crest of ilium) should be used. Raise frame on blocks, at upper and lower ends, to facilitate use of bed-pan and other measures. When necessary to turn patient from frame, shoulders and hips must be so held as to avoid twisting spine.

Bradford Abduction Frame.

Construction.—*Materials.*—Standard three-quarters-inch gas-pipe and elbows; for canvas covers, 12-ounce duck (Army standard) and half-inch grommets.

Inside Measurements of Frame.—Length six feet; width at top sixteen inches, at bottom three feet; point of bend to accommodate for difference in width is thirty-seven inches from top (35 from bottom), and one side only is bent.

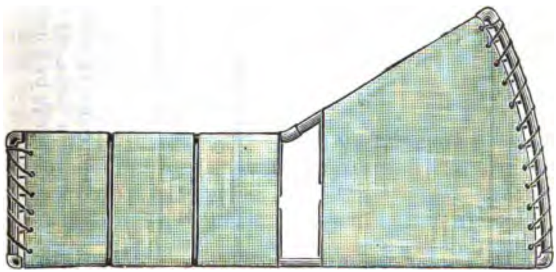

Fig. 65.—Bradford abduction frame.

Size of Covers.—Upper covers, twelve by thirty-four inches; lower cover, thirty-four inches wide at top and seventy inches at bottom, and thirty-three inches long.

Indications for Use.—Hip fractures and joint affections requiring the abducted position, in which plaster-of-Paris casts (the fixation method of choice of American surgeons) cannot be used at once on account of size and location of wounds.

Application.—Covers must be applied so as to make frame suitable for right or left side as indicated, and must be taut, with five or six inches' separation to allow use of bed-pan; when necessary to support buttocks, opening may be closed by a piece of muslin or canvas, or a towel, drawn

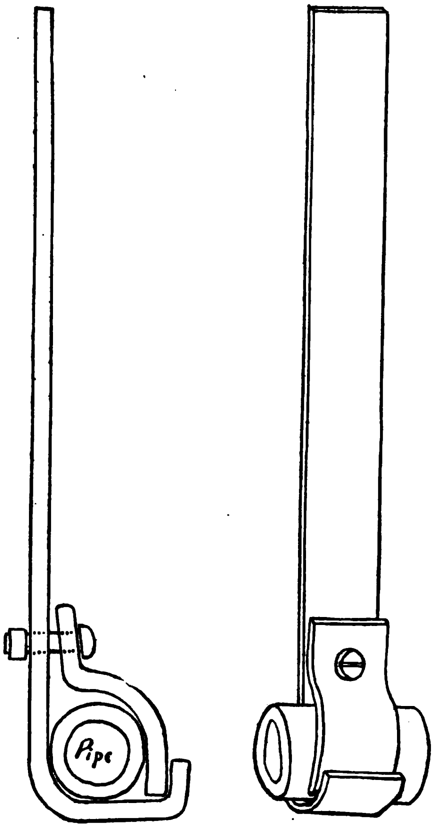

FIG. 66.—Drawings for attachment to Bradford frame to which the bandages, which have been passed through the loops of the extension strips, are tied, thus enabling the heel to be lifted off the frame. Made from flat iron bar $\frac{3}{16}$ by $\frac{3}{4}$ inch. One-half actual size.

tightly around the frame and fastened with safety-pins, or by a piece of tin or other sheet metal with its ends bent over the side bars, which may be slipped up under the back when pan is used. Place patient on frame so that anal opening is opposite center of opening in canvas. Fix patient by a swathe encircling pelvis and frame and another just below shoulders. Secure counter-traction by carefully padded perineal straps, applied to the groins or to opposite groin only and fastened to top bar of frame; secure traction by the usual adhesive strips, but with ends provided with loops reaching to bottom of heel and through which bandages are passed and tied to special removable extension attachment or to lower bar of frame at point giving degree of abduction desired.

Care and Precautions.—Guard against sagging of buttocks into opening by keeping it as narrow as possible or by the methods above mentioned. A pad under the knees to prevent strain on posterior ligaments and another under lumbar spine (its lower edge must not extend below crest of ilium) should be used. Support leg properly if extension attachment is used. Raise frame on blocks at ends to facilitate use of bed-pan and other measures. Remove the perineal straps one at a time, first lowering upper end of frame to secure counter-traction from weight of body, for five minutes at four-hour intervals for the first day and twice daily afterward to permit of proper care of skin area beneath; replace straps exactly, so as to maintain the "fixed distance" established in the beginning. If necessary, the foot of the frame may be kept constantly higher than the head. Guard against outward rotation of the leg. Keep the feet supported at right angles and protected from the weight of the bedclothes. The swathe around the chest may be removed and the shoulders turned slightly to facilitate washing of the upper part of the body, but all necessary washing of the buttocks must be done without disturbing the position.

* Long Liston Splint.

The Board recommends, for transportation only, the use of the long Liston hip and thigh splint, which is the one exception to the open rust-proof iron-wire type of splints.

As usually applied the splint offers no support posteriorly, which is a serious disadvantage in hip-joint and upper thigh injuries. It should rarely be used for these conditions.

Description of Splint.—The splint consists of two pieces of flat wood of unequal lengths. The wood is ½ inch thick and 3 inches wide. The shorter of these two pieces is 14 inches long and to its upper end is fastened a wooden cross-bar, 9 inches long and 2 inches wide, penetrated at either end by an inch hole through which bandage material may be run for fastening the splint to the thorax. The longer of these two pieces of wood is 32 inches in length and is perforated at the center through its

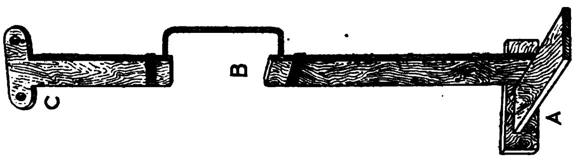

Fig. 67.—Long Liston Splint. *A*, foot-piece adjustable to different lengths of leg; *B*, interrupting bridge; *C*, thoracic bar.

lower 15 inches by small holes 2 inches apart; these holes receive the thumb-screw set-nut of the foot-piece. These two pieces of wood are joined together by a bridge of iron wire, ⅜ inch in diameter; the span of this bridge is 9 inches and its elevation is 2 inches. The wooden foot-piece is 12 inches in length, 4 inches in width, and ¾ inch in thickness, set at right angles to the lower leg splint and adjustable to different lengths of limbs by means of the thumb-screw set-nut and holes. If an abducted position of the limb is desired the iron-wire bridge may be bent to accomplish this purpose.

Patient always recumbent.

Identical splints for right and left sides of body.

Uses.—(*a*) Multiple injuries to the body and limb requiring fixation for comfortable transport.

(*b*) Injuries to the pelvis requiring fixation in transport.

(*c*) Injuries to the hip-joint requiring fixation and abducted position in transport.

* Additional Splinting Material.

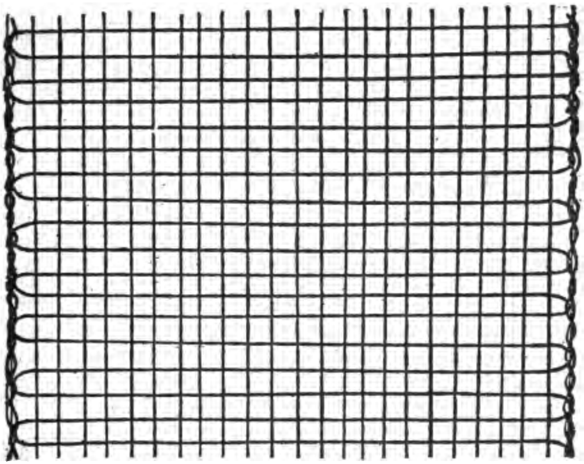

Fig. 68.—Wire gauze. Furnished in rolls, one yard long by six inches wide.

Uses.—For supporting slings on wire splints where wounds are discharging profusely or irrigations are used; for making light splints; for reinforcing plaster-of-Paris bridges.

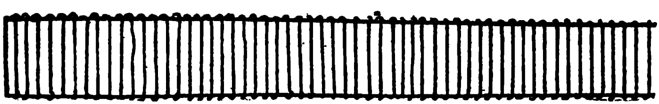

Fig. 69.—"Ladder splint," of galvanized iron wire. The parallel side pieces are of one-eight-inch wire and three and a half inches apart; the cross pieces are of one-sixteenth-inch wire, slightly arched and three-quarters of an inch apart. The material is furnished in pieces thirty inches long and may be cut in the desired lengths by a wire cutter or a file.

Uses.—For coaptation splints (in place of the simple straight splints) or for fixation of the hand, forearm, elbow, foot or knee.

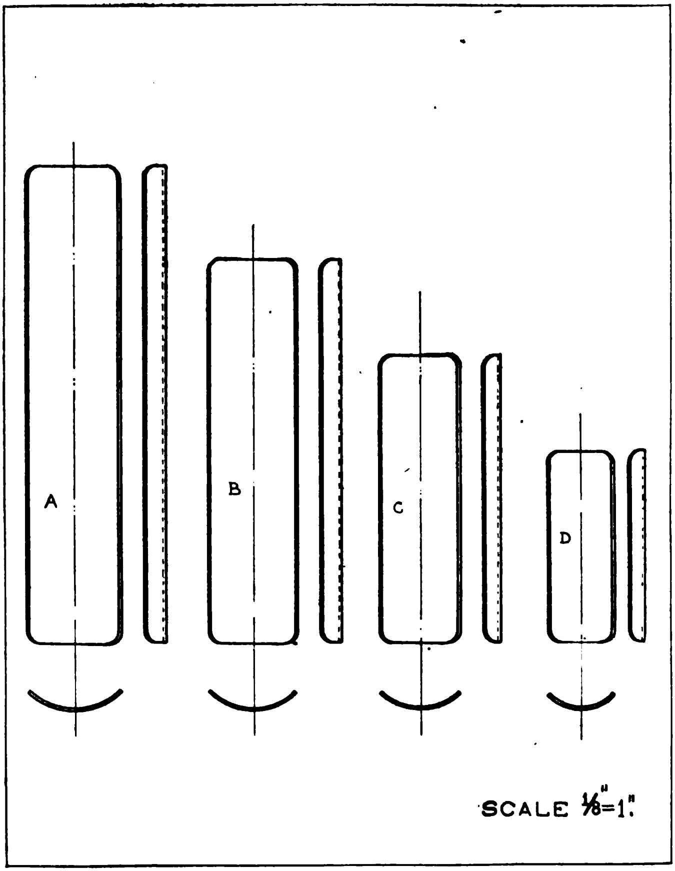

FIG. 70.—Simple straight splints; four sizes. (Jones.)

SIMPLE STRAIGHT SPLINTS. (JONES.)

CONSTRUCTION.—*Material.*—Flat sheet iron, No. 20 (Stubb gauge); asbestos felt, ½ inch.

For working drawings see Fig. 70.

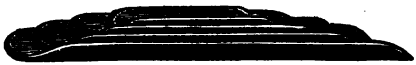

FIG. 71.—Simple straight splints. (Jones.)

INDICATIONS FOR USE.—May be used for (*a*) first-aid fixation, (*b*) coaptation splints, (*c*) fracture of the forearm, including Colles's fracture, and (*d*) lengthening other splints that are too short.

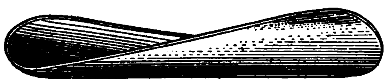

FIG. 72.—Method of twisting to adapt splint to shape of part.

APPLICATION.—Mold by twisting to fit part if required.

CARE AND PRECAUTIONS.—Usual ones only.

*THOMAS'S KNEE SPLINT.

CONSTRUCTION.—*Materials.*—Iron rods, five-sixteenths inch in diameter; felt and leather for padding and covering the ring.

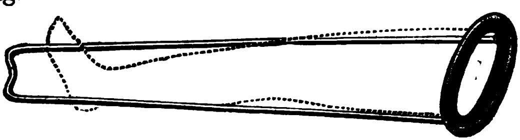

FIG. 73.—Thomas's knee splint.

Measurements.—Inside bar, 44 inches; outside bar, 49

inches; ring is furnished in two sizes, 8 and 9 inches in diameter inside measurement. For detail of end see Fig. 79, *C*.

Indications for Use.—All fractures of femur except those through hip-joint and many of those below trochanter for which the abducted position is required; also joint affections of hip and knee which require traction.

Application.—To obtain size of ring needed measure horizontal circumference of thigh at groin and add one and a half inches; to obtain length add six to eight inches to distance from groin to bottom of heel. Apply traction strips of adhesive in usual manner, but with ends provided with loops reaching to bottom of heel and through which bandages are passed for fastening to bottom of splint. Slide ring of splint over foot and up leg against groin, carefully maintaining proper traction meanwhile; then pass the bandages which have been previously attached to the traction strips around the outside of the upright and tie them to the lower end of splint, making degree of traction required. A more accurate adjustment is secured by inserting one end of a long nail or a piece of stiff wire between the two traction strips just above the lower end of the splint (Fig. 74), twisting them until the desired degree of traction is secured, and then maintaining it by slipping the other end under (or over) one upright (Osgood). "A posterior knee-splint (simple straight splint), short enough just to avoid the gluteal fold at the upper end and the heel at the lower end, is then slung between the side bars to support the limb; simple straight splint can be applied (anteriorly) if required, and the whole bandaged compactly together."

If ring is too large, place a pad of sufficient size inside ring at its junction with outer bar to prevent inner portion of ring from slipping across the perineum or use "plug" provided for this purpose. If ring is too small, saw through it in front and open it as required. It is of no consequence if splint is longer than required.

FIRST-AID APPLICATION OF THOMAS'S KNEE SPLINT.—For first-aid extension a skewer may be used; this is made of

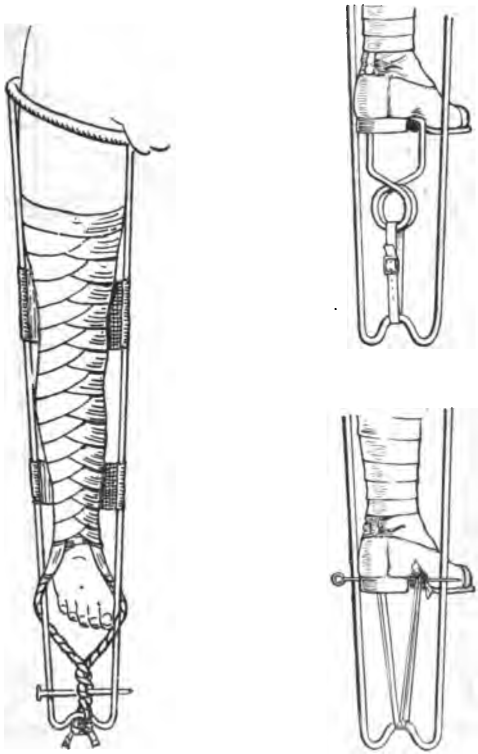

FIG. 74.—Twister for adjusting extension (on left). Spring clip for extension in transport (above on right). Skewer extension (below on right).

steel wire, $\frac{1}{4}$ inch in diameter, sharpened at one end and bent into a half-inch ring at the other, and should be about $8\frac{1}{2}$ inches long. The first dressing is put on through a cut in the

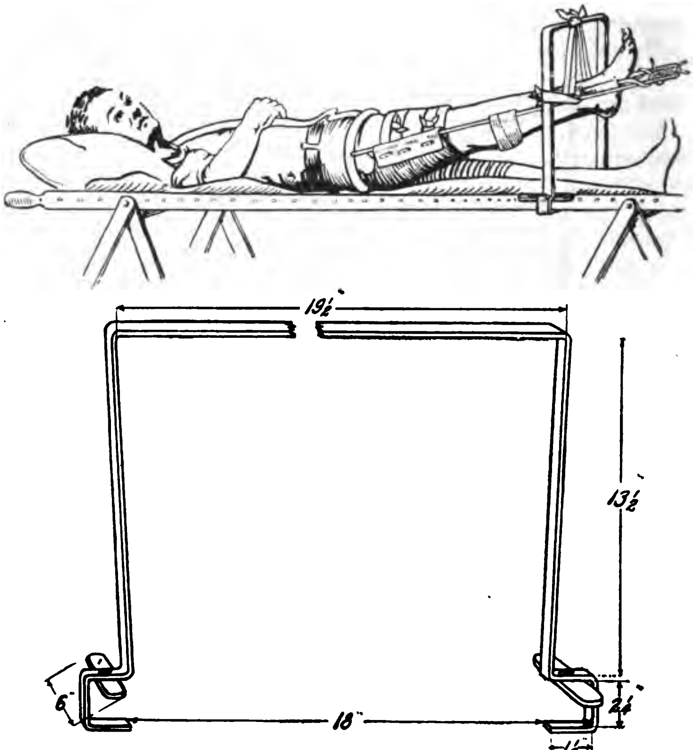

FIG. 75.—Splint support, attached to stretcher; a modification of the British type. Working drawing below.

trouser, the Thomas knee splint is applied, and then the skewer is run through the shoe between the sole and the upper at the proper angle to give the desired degree of inward or outward rotation of the leg. The skewer thus rests on the side bars of the splint, and traction is made by a bandage, handkerchief, or other piece of cloth fastened around the ends of the skewer and tied to the bottom of the splint. Hammocks are then placed under the leg and fastened to the side bars, and the case is ready for transportation to the casualty clearing station.

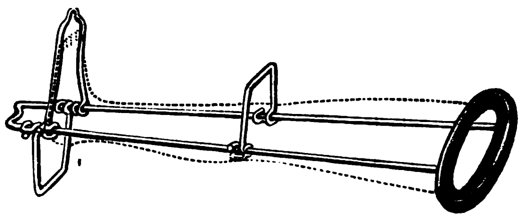

FIG. 76.—Thomas's knee splint with detachable wire foot-piece, brace support and reinforcing attachment in place.

CARE AND PRECAUTIONS.—"This (splint) is usually applied when extension of the femur is required; therefore pressure over the ischium may be great, but this can be relieved by raising, lowering, or abducting the limb from time to time. The skin surface lying under the ring should be frequently changed and kept dry and well powdered. The foot end of the splint must be either slung or supported to prevent pressure under the heel, and if the foot has been left free it should be supported at right angles by a pillow or otherwise." Except when used for transportation, it is better to suspend the splint by means of an overhead frame (see Fig. 104). Pressure on the groin may be relieved by moderate traction attached to the lower end of the splint.

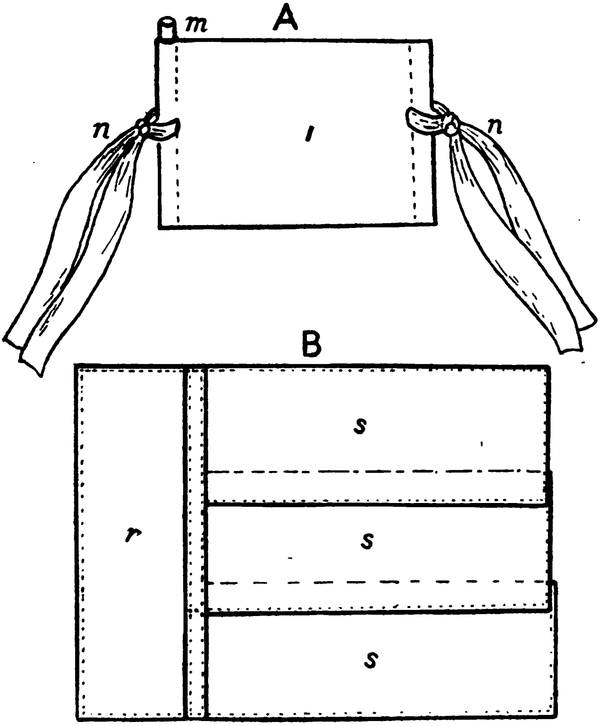

FIG. 77.—*A*, pattern for sling (Sinclair) for Thomas's knee or similar splint. Made in 6 sizes: 6, 7, 8, 9, 10 and 12 inches long and 6 inches wide. *m*, small stick inserted in casing; *n*, tapes for tying to uprights. *B*, pattern for the thigh sling (C. T. Butler) made like half of many-tailed bandage. May be made of canton flannel backed with muslin or of two thicknesses of muslin. *r* is 11 inches by 4 inches. *s* is 11½ inches by 4½. For permanent use this may be fastened with safety-pins, but when it must be loosened for dressings it may be fastened to the uprights by means of the ordinary paper clips.

*Stocking Extension.

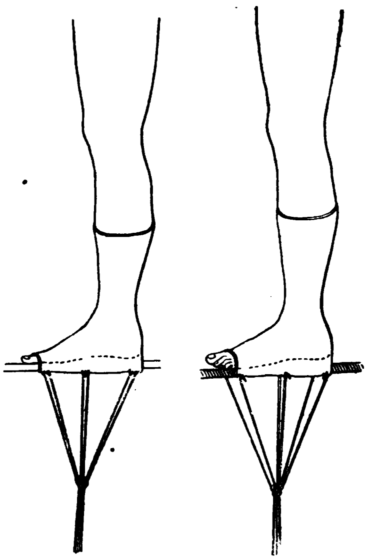

Fig. 78.—Stocking extension. An excellent traction may be obtained by a light-weight army sock. The lower leg, ankle, and foot, with the exception of the toes and the plantar surface, are painted with glue and the sock slipped on. The toe of the sock is cut off and a piece of light splint wood or the ladder splint material, cut the length of the foot, is inserted between the sole and the sock. Traction may then be made on this by means of pieces of bandage or cord passed through the sock and around the wood or the rods of the ladder splinting.

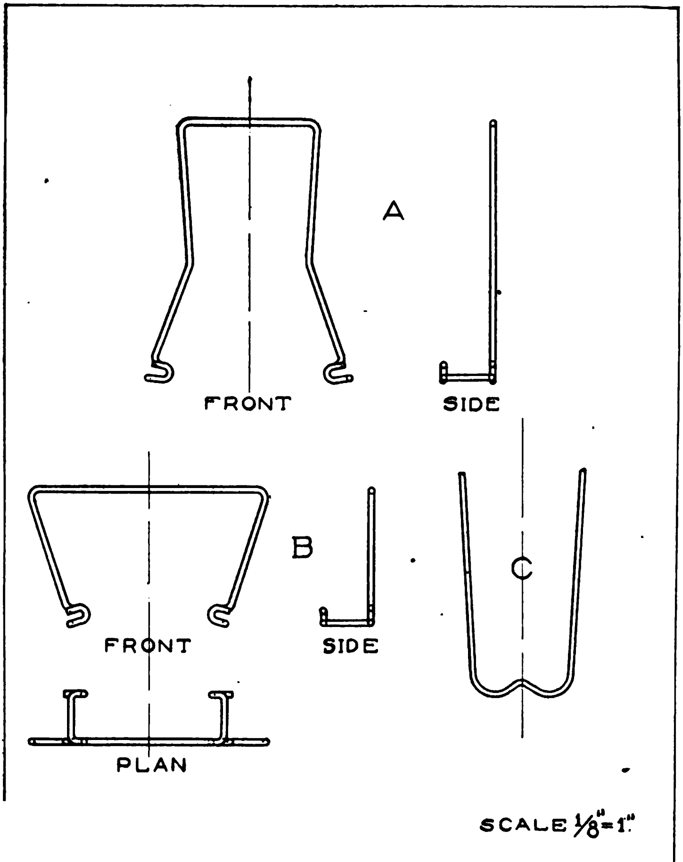

FIG. 79.—*A*, foot-piece for Thomas's knee splint; *B*, reinforcing. attachment and brace support for same; *C*, detail of lower end of Thomas's splint.

DETACHABLE WIRE FOOT-PIECE FOR THOMAS'S KNEE SPLINT.

CONSTRUCTION.—*Material.*—Iron rod, one-quarter inch in diameter.

For working drawing see Fig. 79.

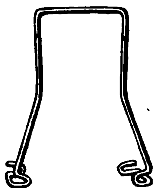

FIG. 80.—Wire foot-piece.

INDICATIONS FOR USE.—To prevent toe-drop and rotation of foot.

APPLICATION.—Snap into place and fasten with adhesive plaster or a bandage.

DETACHABLE WIRE REINFORCING ATTACHMENT AND BRACE SUPPORT FOR THOMAS'S KNEE SPLINT.

CONSTRUCTION.—*Material.*—Iron rod, one-quarter inch in diameter.

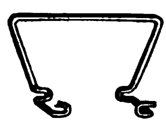

FIG. 81.—Reinforcing attachment and support.

For working drawing see Fig. 79.

INDICATIONS FOR USE.—To strengthen brace, or act as a support to raise lower end of brace.

APPLICATION.—As a reinforcing piece, snap into place just below the knee, or at desired point, *top up*, and fasten with adhesive or a bandage. As a support, apply in same manner, *top down*, near lower end of brace (see Fig. 76).

KNEE-JOINT ATTACHMENT FOR THOMAS KNEE SPLINT.

CONSTRUCTION.—*Material.*—Sheet iron, three-sixteenths inch; steel wire, one-fourth inch; standard one-fourth-inch machine bolts, three-fourths inch long; standard one-fourth-inch square nuts; standard one-fourth-inch winged nut.

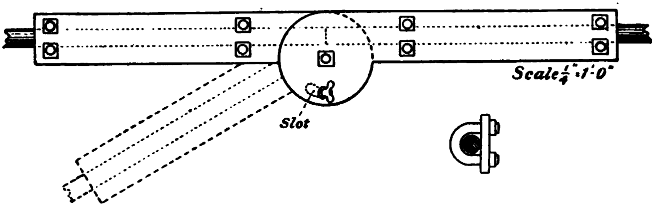

FIG. 82.—Drawing for adjustable knee-joint which may be attached to the uprights of the Thomas knee splint *in situ* and the uprights not divided until after the joint is in place.

INDICATIONS FOR USE.—To permit early motion of the knee and prevent ankylosis.

APPLICATION.—This is intended for application *without removal of the splint* from the patient. Apply attachment with joint below uprights. Fasten firmly to uprights by U-bolts. Then, when both sides have been attached, saw through the uprights opposite joint.

CARE AND PRECAUTION.—It will usually be advisable to change the position of knee once a day only, leaving it in flexed position for several hours and then returning it to straight position; only a few degrees flexion should be used at first. Slot allows flexion of thirty degrees which will

ordinarily be all that is advisable. *Before knee is flexed be sure that sling which supports lower end of femur extends as closely as possible to joint line.*

HODGEN'S SPLINT.

CONSTRUCTION.—*A. Materials.*—Bessemer steel, copper-coated wire, five-sixteenths inch in diameter, for main part of brace; one-fourth inch for large attachments; three-sixteenths inch for small attachments; or use iron rod.

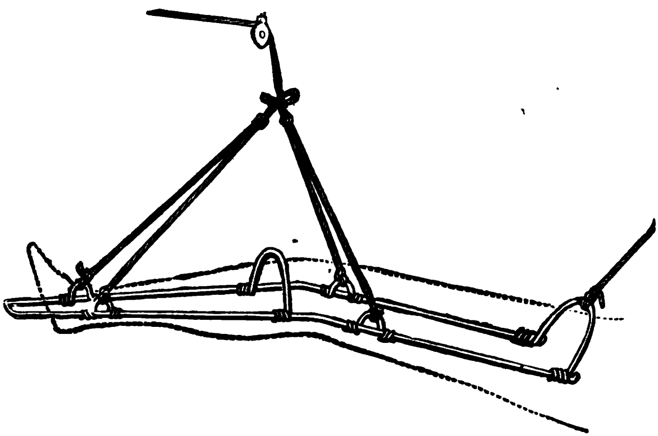

FIG. 83.—Hodgen's splint, army pattern.

Measurements.—Uprights, both sides same length, forty-eight inches, bent twenty-eight inches from end of brace to an angle of thirty degrees; width at bottom four and a half inches; width at top ten and a half inches. Upper attachment is nine inches wide and six inches high (above the uprights), with ends twisted three times around uprights. Lower attachment is six and a half inches wide and five

inches high, with ends twisted in same way. The four small attachments (for suspension), are one inch wide and one and a fourth inches high, with ends twisted twice around uprights.

B. This splint may be readily made from a Thomas knee splint by sawing through posterior half of ring just back of each upright, bending uprights at knee to about 130 degrees (or to angle desired), and attaching the adjustable wire foot-piece and adjustable wire reinforcing attachment.

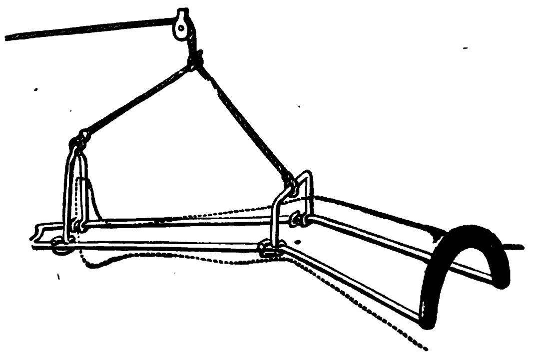

FIG. 84.—Hodgen's splint, made from Thomas's knee splint.

INDICATIONS FOR USE.—Fractures of femoral shaft.

APPLICATION.—Support leg in splint by slings, pinned or clipped on in usual manner, and then suspend whole by traction pulley attached to overhead (Balkan) frame; secure any desired degree of traction or elevation by changing the direction of the traction. Traction by adhesive strips is often unsatisfactory, as with the knee bent it must be applied to the lower thigh, and this is frequently impossible because of wounds; this difficulty can sometimes be overcome by using the Hennequin method of making the traction.

CARE AND PRECAUTIONS.—Much the same as for the Thomas splint.

BLAKE'S SPLINT.
(MODIFICATION OF THOMAS'S KNEE SPLINT.)

CONSTRUCTION.—*A. Materials.*—Iron rod, five-sixteenths inch in diameter; felt and leather for padding the ring; one-inch webbing and buckles.

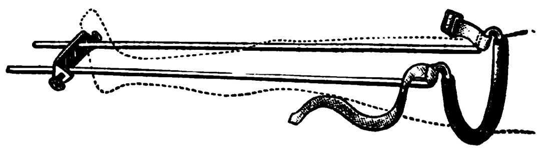

FIG. 85.—Blake's splint.

Measurements.—Uprights to offset at top forty-two inches; offset is two inches wide and one and one-fourth inches deep; ring (from level of uprights) is one-half-inch circle, ten inches in diameter.

B. To make this splint from a Thomas knee splint, saw through anterior half of ring just in front of both uprights. Also saw through uprights as close to lower end as possible. Apply Blake's foot-piece.

INDICATIONS FOR USE. APPLICATION, CARE AND PRECAUTIONS.—Same as for Thomas's knee splint.

LOWER LEG FRACTURE SPLINT.
(MODIFIED FROM THOMAS'S KNEE SPLINT. SILVER.)

CONSTRUCTION.—Thomas's splint is modified as follows: Remove anterior half of ring by sawing through on each side just in front of each upright (but splint may be used with ring intact); with knee (of well leg) fixed to about 70 degrees to 80 degrees, take measurement from groin to

center of knee and subtract two or three inches, and bend uprights at this distance from ring to angle of 75 degrees to 80 degrees; attach removable supporting band about two or three inches below point of angle and removable foot-piece.

INDICATIONS.—Spiral fractures of both bones of lower leg which cannot be held by other methods. Advantages claimed over straight splints are (*a*) relaxation of gastrocnemius, and (*b*) prevention of rotation of fragments; any necessary degree of traction may be exerted during setting of fracture and the position thus secured maintained by fastening traction straps to bottom of splint.

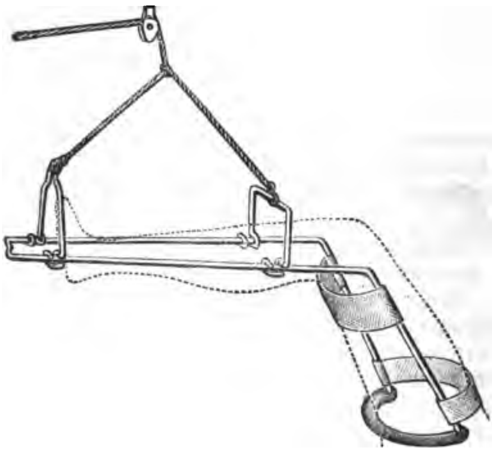

FIG. 86.—Lower leg fracture splint.

APPLICATION.—Counter-extension is secured by a half-band of canvas or strong muslin fastened to the upright just below the knee posteriorly; a small half-band, two or three inches wide, is placed close to the groin anteriorly to maintain flexion of the knee; extension is secured with the usual

adhesive strips with loops attached to the lower end, through which bandages are passed; or in case of fractures, close to the ankle. Strips may have to be applied in an irregular manner to secure firm hold.

Thigh being fixed as just described, fracture is now reduced, and required traction maintained by bandages, previously passed through loops, being passed around outside of upright and tied to bottom of splint.

Lower leg is supported underneath by straps attached to upright. Foot is bandaged to foot-piece, thus preventing rotation of fragments. By proper use of straps, or bandages, either fragment may be raised, lowered, or moved laterally.

Suspend splint by means of overhead frame.

CARE AND PRECAUTIONS.—Same as with ordinary Thomas splint. Thigh must be held firmly and be suspended so that lower leg is horizontal.

COMBINED ANKLE AND LOWER LEG SPLINT. (JONES.)

CONSTRUCTION.—*Materials.*—Flat sheet iron, No. 20 (Stubb gauge); flat iron bars, one-half inch by one-quarter inch; asbestos felt, one-half inch.

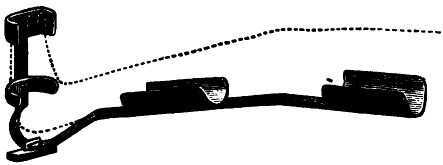

FIG. 87.—Ankle and lower leg splint.

For working drawings see Fig. 88.

(The location of the heel band has been changed.)

INDICATIONS FOR USE.—All fractures of lower portion of tibia and fibula, and those through ankle-joint.

"It allows of easy access to the wound, and can without difficulty be modified to suit a special case. Fortunately,

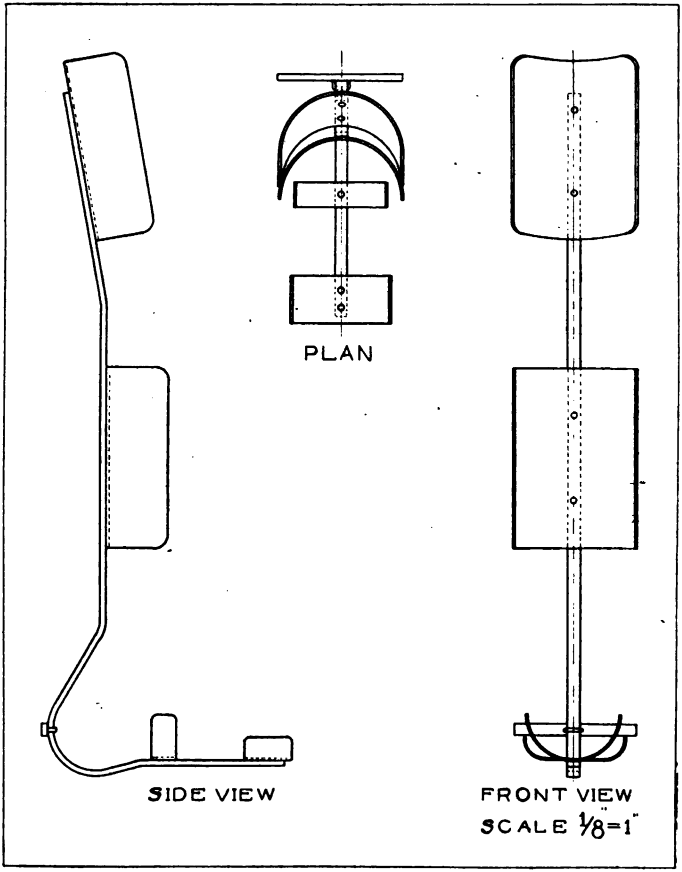

FIG. 88.—Combined ankle and lower leg splint. (Jones.)

in gunshot wounds the spiral fracture is rare, and, generally speaking, one bone remains unbroken."

APPLICATION.—Foot should always be held at right angles and in slight supination, if condition permits; if it is necessary to hold it in plantar flexion, this may be done by bending upright at or slightly above back of ankle-joint; supination or pronation, or adduction or abduction may be secured by giving upright proper twist.

CARE AND PRECAUTIONS.—Heel must be kept from resting on upright; place small pad just above heel between leg and upright. "This splint should be supported on a graduated pillow which is thicker under the knee."

RECTANGULAR FOOT SPLINT. (JONES.)

CONSTRUCTION.—*Materials.*—Flat sheet iron, No. 20 (Stubb gauge); flat iron bars, one-half inch by one-quarter inch; asbestos felt, one-half inch.

For working drawings see Fig. 90, *A*.

(The foot-piece has been modified so that the brace can be used for either foot and an adjustable flange added.)

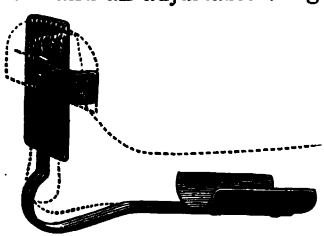

FIG. 89.—Rectangular foot splint. (Jones.)

INDICATIONS FOR USE.—All injuries to foot in which it is necessary to fix ankle. (If satisfactory access to wounds is not afforded, use wire foot splint (Fig. 102).

APPLICATION.—The foot should always be held at right angles and in slight supination, if condition permits; if it

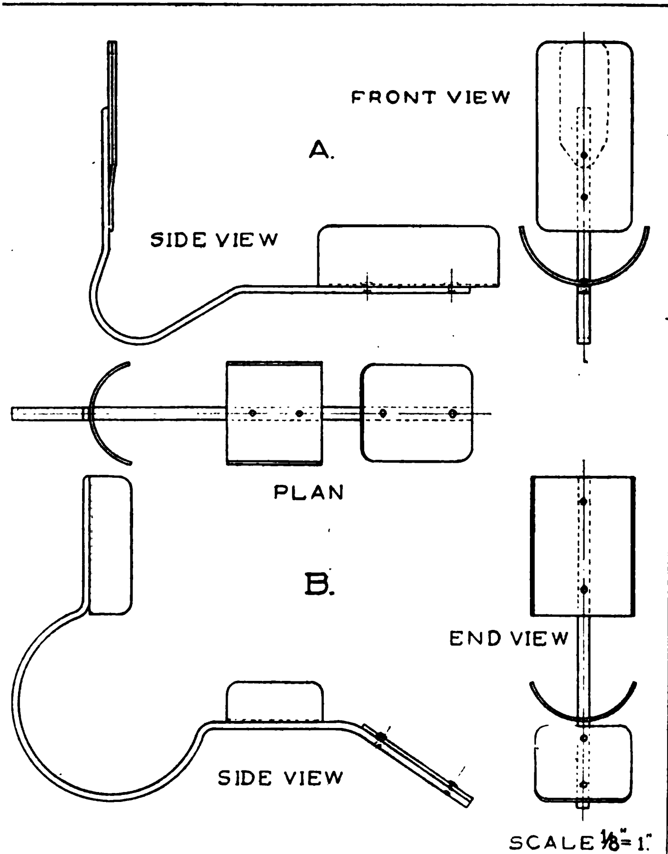

Fig. 90.—*A*, rectangular foot splint; *B*, elbow splint. (Jones.)

is necessary to hold it in plantar flexion, this may be done by bending upright at or slightly above back of ankle-joint; supination or pronation, or adduction or abduction may be secured by giving upright proper twist.

CARE AND PRECAUTIONS.—Heel must be kept from resting on upright; place small pad just above heel between leg and upright. Support leg on a graduated pillow to keep knee slightly bent.

*POSTERIOR WIRE LEG SPLINT. (CABOT.)

"The splint consists of a quadrilateral form of one-quarter-inch wire seven inches in width at the upper portion, which is bent at right angles and concave to conform to the convex surface of the upper thigh. It

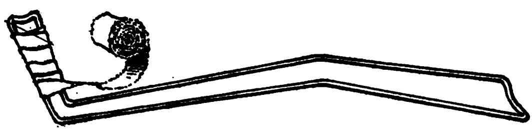

FIG. 91.—Posterior wire splint. Showing method of wrapping.

narrows at the heel and at this point is bent upward to form a right-angle foot-piece twelve inches in height and four inches wide. For use, this frame of wire is bandaged and padded and usually bent slightly at the knee. It is retained in position on the limb by adhesive-plaster straps applied:

"1. As near the upper limit of the splint as possible.

"2. Above the ankle-joint proximal to the malleoli.

"3. About the foot just proximal to the great toe-joint.

"Splints made of light splint wood or the wire-ladder splint material are applied posteriorly and on either side of the limb, and are fastened and retained by webbing straps and buckles. The ease of application and adaptability of this splint present the danger of its too general employment.

"USES.—(*a*) Injuries to the soft parts of the lower limb requiring fixation in transport.

"(*b*) Slight injuries to the knee or ankle requiring fixation in transport.

"(*c*) Fractures of the fibula or tarsus.

"The Board recognizes the frequent maltreatment encountered by the contemporary use of the ordinary ham splint and the straight poster or wood splint with a right-angle foot-piece. The application of the posterior wire splint should be scrupulously restricted to wounds of muscular tissue, slight injuries to the knee-joint, fractures of the fibula, injuries to the ankle-joint and tarsus not requiring traction in addition to fixation.

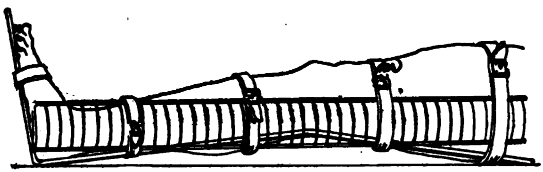

FIG. 92.—Posterior wire splint. Splint applied with ladder side splints.

"The traction and counter-traction principle of the Thomas splint and its modifications should be maintained in all cases where there is solution of continuity of the bone with the possibility of displacement of fragments, or where the traumatic lesion of the joint is likely to result in serious infection and muscular contraction."

ABDUCTION ARM SPLINT. (JONES.)

CONSTRUCTION.—*Materials.*—Flat sheet iron, No. 20 (Stubb gauge); flat iron bars, one-half by one-quarter inch; asbestos felt, one-half inch; one-inch webbing and buckles.

For working drawings see Fig. 93. (This splint has been modified so as to be adapted for either right or left side. The side piece has been made adjustable.)

INDICATIONS FOR USE.—An efficient splint in certain fractures of upper end of the humerus, fracture of tip of acromion, bursal affections, and for maintaining the shoulder in position, abducted slightly forward and rotated slightly inward (see page 106); in cases where ankylosis is to be expected the joint at the elbow permits motion at this point.

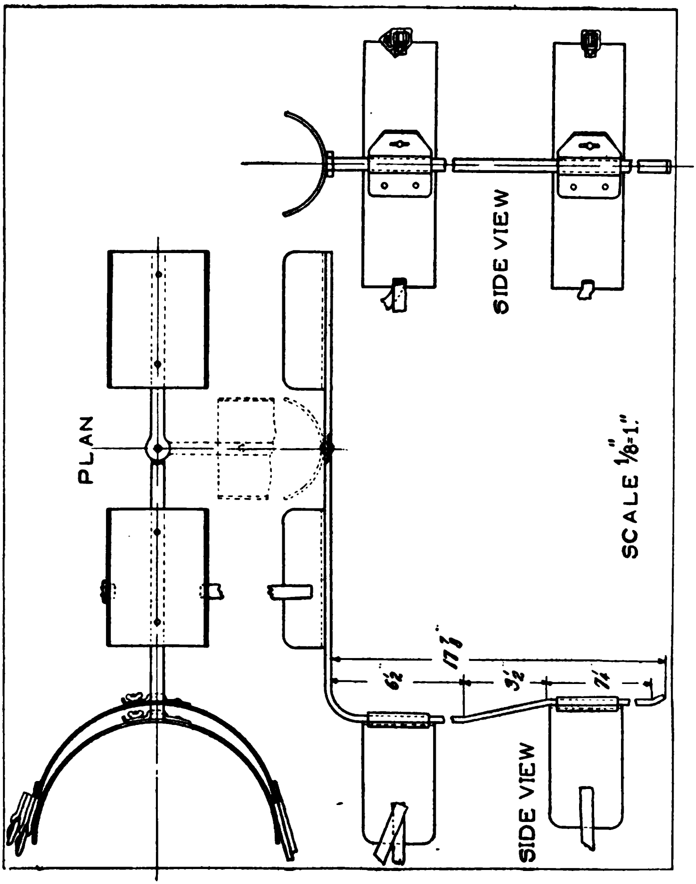

FIG. 93.—Abduction arm splint. (Jones.)

APPLICATION.—Care must be taken to fit the brace accurately not only so that it will conform to the under surface of the arm and chest and thus properly support the upper end of the humerus but also so that the elbow will be held slightly in front of the coronal plane of the body. If the joint for the elbow does not fall at the proper point but is too near the body, lengthen the humeral portion of the upright at the expense of the chest portion; if it is too far from the body, shorten it by the reverse procedure.

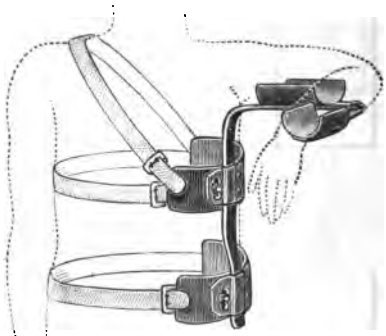

FIG. 94.—Abduction arm splint. (Jones.)

CARE and PRECAUTIONS.—Once splint is applied in cases where ankylosis is feared or expected, position of shoulder must not be allowed to change; when for any reason it is necessary to remove splint, position of arm must be maintained constantly until splint has been reapplied. Ankylosis is often slow; when it seems firm, splint should be removed at first for short interval only and for a long time after it has become possible to remove it for the day it is still wise to wear it at night in order to avoid gradual loss of abduction through possible yielding of young tissue (unless, indeed, radiogram has demonstrated bony union).

* Extension Arm Splint.

(Made from Thomas's Knee Splint.—Jones.)

Construction.—*Materials.*—Iron rod, one-quarter inch in diameter; felt and leather for padding and covering ring.

Measurements.—Both uprights are 36 inches; the ring is seven inches in diameter, inside measurement. For detail of end of splint see Fig. 79, *C.*

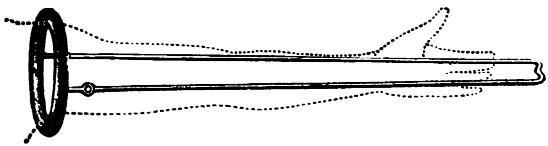

Fig. 95.—Extension arm splint.

Indications for Use.—To maintain extension of humerus in abducted position while patient is recumbent; also used with arm at side as a quick and efficient method for maintaining extension during transport.

Application.—Apply extension strips as for fracture of femur, with loops at ends through which bandages are passed; slip splint over arm until ring rests against axilla, and then carry the bandages which were passed through the loops around uprights and tie them to lower end of splint, making required extension; use simple straight splints as required, and bandage whole compactly together. Size of ring will rarely cause trouble but if ring is too large, a sufficient pad may be placed, if necessary, under upper half. If too small, saw through near front upright and separate. Hand should be midway between pronation and supination.

Care and Precautions.—Traction must not be so great as to cause numbness or pain from pressure of the axillary ring; also owing to the destruction produced by modern

missiles, great care is necessary to avoid overextension with resulting non-union.

*Methods of Using the Extension Arm Splint.

A number of ingenious ways of using the extension arm splint, both singly and in combination, have been suggested by Osgood, several of which are here illustrated.

The ordinary method of application is shown in Fig. 96. Used in this manner it is adapted to the treatment of the following conditions:

(a) Injuries to the shoulder-joint.
(b) Injuries to the shaft of the humerus.
(c) Injuries to the elbow-joint.
(d) Injuries to the forearm.

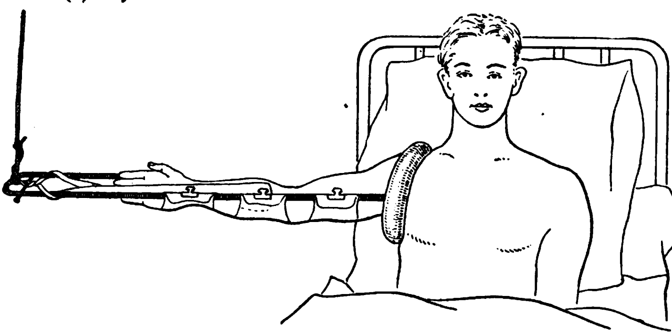

Fig. 96.

Where the shoulder is so injured as to make the application of the extension arm splint impossible or undesirable, the regular Thomas knee splint may be applied over the uninjured shoulder (for shoulder and arm injuries), as shown in Fig. 97.

In both the cases just illustrated the abducted position of the arm cannot be maintained if ambulation is permitted. This is made possible, however, in the first case by the ingenious combination of two extension arm splints, as shown in Fig. 98, and in the second case by adding, in a similar manner, an extension arm splint to the regular knee splint.

Other combinations are also possible.

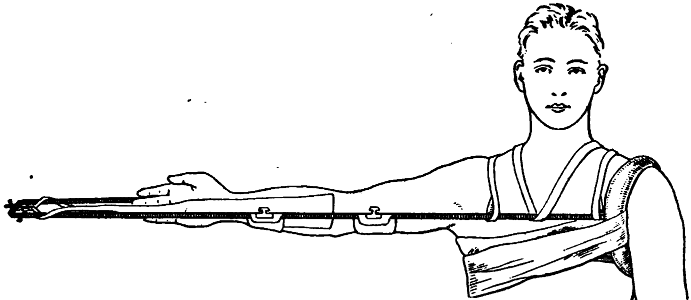

FIG. 97

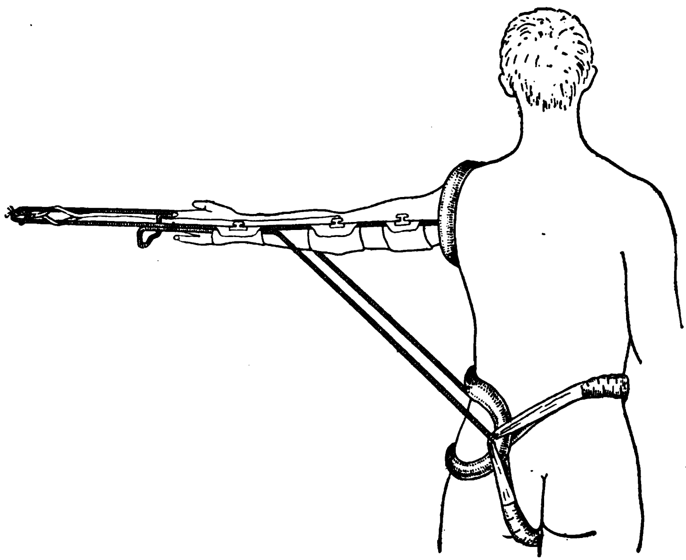

FIG. 98

* HUMERUS EXTENSION SPLINT. (JONES.)

CONSTRUCTION.—*Materials.*—Iron rod, one-quarter inch in diameter; felt and leather for padding and covering ring.

For working drawings see Fig. 100.

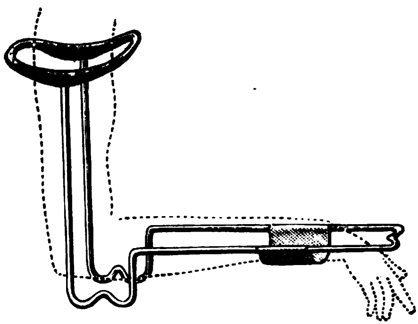

FIG. 99.—Humerus extension splint. (Jones.)

(This splint has been modified so as to be adapted for either right or left side.)

INDICATIONS FOR USE.—A useful splint in fractures of the middle and lower portions of humerus, in case dressings have to be changed frequently, when patient can walk about or sit up in bed.

APPLICATION.—Slip splint over arm until crutch presses against axilla; anterior half of forearm rests upon sling fastened to uprights; make traction by means of bandage passed over forearm, just below fold of elbow, and tied to lowest portion of uprights, and also as is usually necessary,

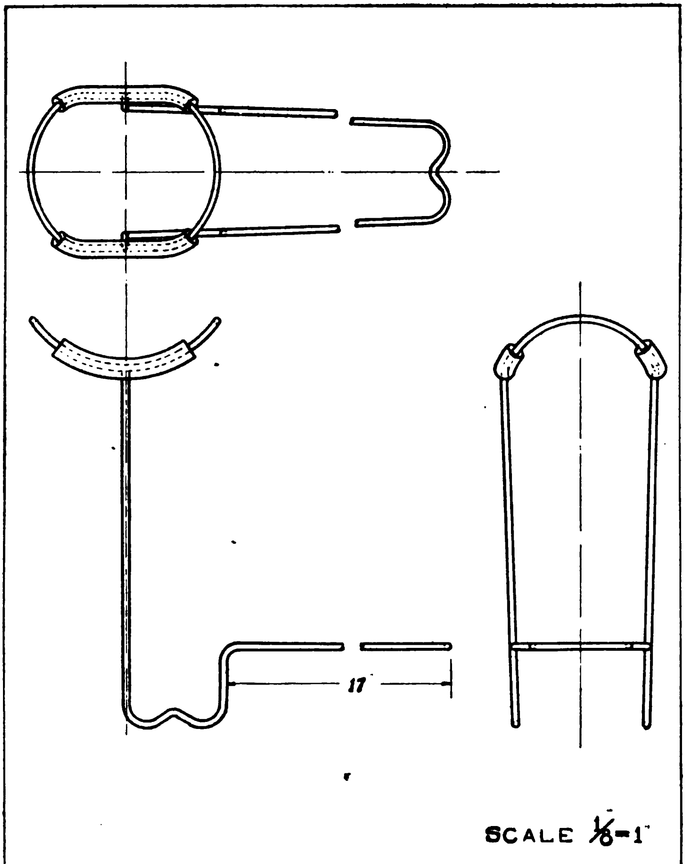

FIG. 100.—Humerus extension splint. (Jones.)

by traction strips of adhesive plaster with ends provided with loops through which bandages are passed for fastening to lowest portion of upright. Hand should be midway between pronation and supination.

CARE AND PRECAUTIONS.—Traction must not be so great as to cause numbness or pain from pressure of axillary ring; also owing to the destruction produced by modern missiles, great care is necessary to avoid overextension with resulting non-union.

ELBOW SPLINT. (JONES.)

CONSTRUCTION.—*Materials.*—Flat sheet iron, No. 20 (Stubb gauge); flat iron bar, one-half inch by one-quarter inch; asbestos felt, one-half inch.

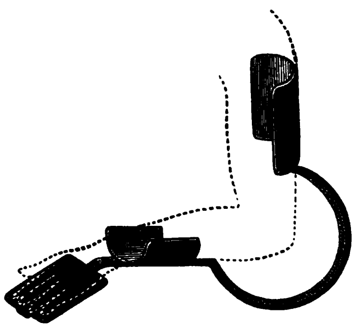

FIG. 101.—Elbow splint. (Jones.)

For workings drawings see Fig. 90, *B*.

INDICATIONS.—Occasionally needed for fractures in and around elbow-joint, in which location of wounds or suppuration prevents use of acutely flexed position; also in joint injuries requiring more complete immobilization than is afforded by a sling.

APPLICATION.—In applying splint be careful to avoid undue pressure from bandage at fold of elbow. Use a simple bandage sling, supporting forearm in lower third only.

CARE AND PRECAUTIONS.—If possible, avoid keeping elbow fixed in same position longer than for ten-day intervals.

HAND, WRIST AND FOREARM SPLINTS. (JONES.) HYPEREXTENSION HAND SPLINT. *SKELETON HYPEREXTENSION HAND SPLINT. LONG HAND SPLINT WITH AN ADJUSTABLE THUMB-PIECE.

CONSTRUCTION.—*Materials.*—Flat sheet iron, No. 20 (Stubb gauge); flat iron bars, one-half inch by one-eighth inch; asbestos felt, one-half inch.

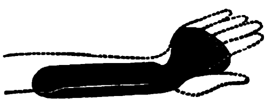

FIG. 102

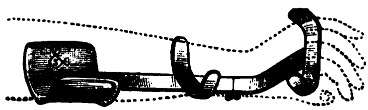

FIG. 103

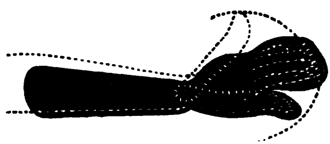

FIG. 104

FIG. 102. — Hyperextension hand (cock-up) splint. FIG. 103. — Skeleton hyperextension hand splint. FIG. 104.— Long hyperextension hand splint with an adjustable thumb-piece.

For working drawings see Fig. 105.

INDICATIONS FOR USE.—In one form or another these splints will be found sufficient for care of all wrist and hand injuries. Good function requires that most injuries of these

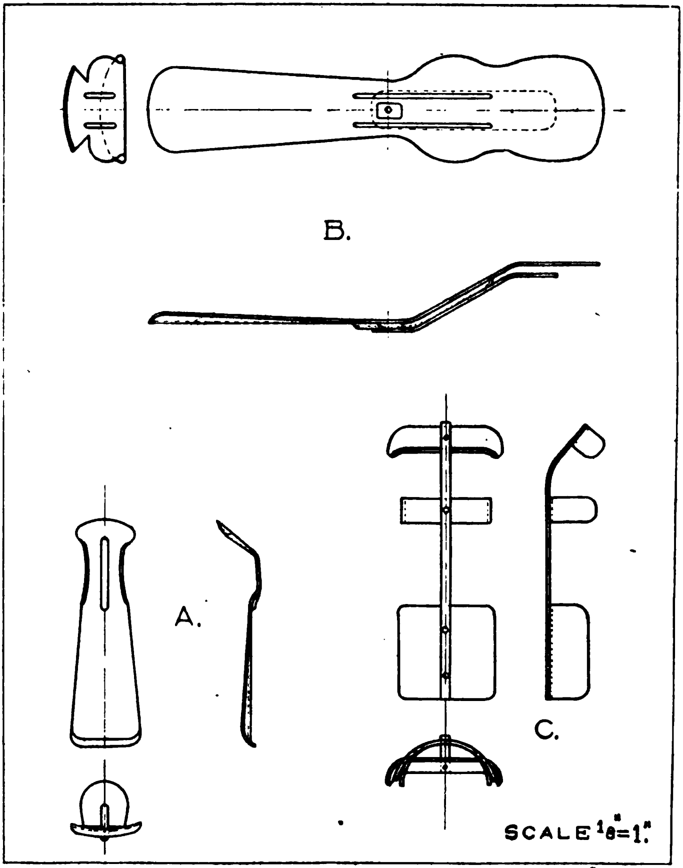

FIG. 105.—*A*, hyperextension hand (cock-up) splint (Jones); *B*, hyperextension hand splint with thumb-piece; *C*, skeleton hyperextension hand splint. (Jones.)

parts, especially all affections producing wrist-drop, be treated with hand in dorsal flexion, usually about 20 degrees, in order to maintain grasping power of fingers. For simple injuries of wrist the small hyperextension splint is sufficient; those complicated by extensive wounds will require the skeleton pattern, which may also be used on dorsal surface by simply bending upright; the other patterns are suitable when the hand is involved.

APPLICATION.—"Care must be taken to fit the wrist flexion accurately to the splint flexion, thus avoiding any possible strain to the carpal joints." To avoid the flattening of the palm with the consequent injury to the palmar muscles and flattening of the palmar arch so often seen it is necessary to be sure that the palmar splint is so cut out or shaped as to prevent harmful pressure on the intrinsic muscles of the thumb and little finger.

PRECAUTIONS.—Skin of palm and that between fingers becomes easily macerated, and hence splint must not be left on too long without changing. Whenever fingers are fixed, care must be taken to allow slight flexion at metacarpo-phalangeal joints.

METHOD OF MAKING SPLINTS OF WIRE.

Heavy wire has long been used for the improvisation of splints of diverse kinds. It may also be used in connection with plaster of Paris for the construction of the most complicated fixation dressings. To obtain the greatest satisfaction from it, it should be handled with method.

Material.—The wire furnished for this purpose is of Bessemer steel, copper-coated, and $\frac{8}{32}$, $\frac{6}{32}$ and $\frac{11}{32}$ in size (selected by committee on standardization). The rods are usually obtained in lengths of ten to twelve feet.

TOOLS.—Only simple tools are required, but the results will be much more satisfactory if the equipment selected by

the committee on standardization is secured. It is desirable to use a triangular file for marking the location of the bends which are to be made. For cutting the lengths, one may use a

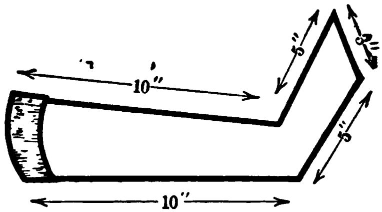

FIG. 106.—Sketch for right-angled foot splint.

cold chisel, hacksaw, or the heavy pliers for cutting wire. The bending may be done with a large monkey wrench or

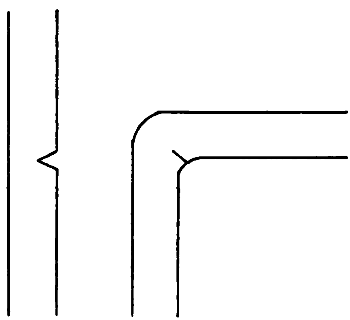

FIG. 107.—Showing how the notch helps to make right-angled bend.

heavy pliers; the best tool for this purpose is, however, the joining pliers used by electric linemen. These pliers have openings of sizes corresponding to the different diameters of

wire or rods, and the openings are knurled so that the rod is very tightly held, with ease.

Method.—It is always best to lay out on paper a rough sketch of the splint to be made; the illustration (Fig. 96) shows the sketch for a right-angled foot splint. This will, according to the sketch, require a rod thirty-three inches long.

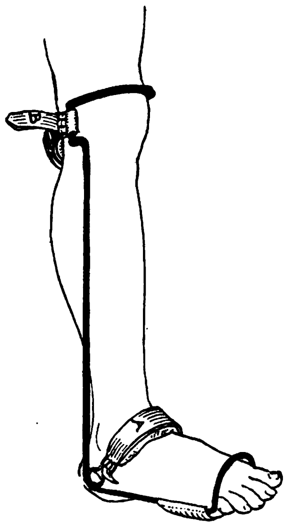

FIG. 108.—Line drawing of wire splint to correct foot-drop. (Osgood.)

The points at which the bends are to be made are measured off and are marked by a rather deep notch, made with the triangular file. Especially if using the heavier rods it is important to make this notch so that it corresponds to the concavity of the bend; this makes it easy to produce a sharp right angle. If the notch is on the convexity of the bend it is likely to break the rod in the bending; if on the concavity,

the notch may be one-fourth the thickness of the rod without damage, and on the other hand, greatly facilitates accuracy.

It is well to finish the splint by means of spreaders of tin or other thin metal and with slings of adhesive plaster.

FIG. 109.—Wire foot-drop splint applied. (Osgood.)

In making splints of more complicated kind it is often necessary to have some way of fastening the ends of the wire together. The simplest method is to do this by wrapping firmly with adhesive plaster. A more secure fastening is obtained by being provided with sleeves of brass tubing which will slip over the wire and with some soldering paste; the paste is pushed into the sleeve ahead of the wire, and it requires now only the heat of a spirit lamp to produce a very firm joint.

ADHESIVE SUBSTITUTES FOR Z. O. ADHESIVE AND MOLESKIN PLASTER.

Several adhesive mixtures are being used as substitutes for the various adhesive plasters. The material used to make the extension strips may be either flannel or flannellette, or the ordinary 4-ply gauze, with webbing straps sewed to the ends.

Heusner's Glue.

Resin	50
Alcohol	50
Benzine (pure)	25
Venice turpentine	5

Powder resin, add half the alcohol, all the Venice turpentine and benzine. Next wash out the measure with the remaining alcohol. Remove glue with benzine or alcohol.

A New Adhesive for Applying Extension.[1]

Ordinary glue	50 parts
Water	50 "
Glycerin	2 "
Calcium chloride	2 "
Thymol	1 "

The glycerin and calcium chloride are both deliquescent and take up the perspiration, which keeps the glue from getting brittle, and, more important still, allows the perspiration to take place. This prevents the skin from getting sodden, in which condition bacteria may flourish and give rise to skin troubles.

The thymol is added to prevent putrefaction and diminish the smell. Every time the adhesive is heated the odor gets less and less. Experiments have proved that bacteria do not grow on this preparation. Air-tight tins which hold about a pound are filled and sterilized at 100° C. and placed in store. When required the contents are melted in a water-bath, and set aside a few minutes to cool.

The adhesive is applied with the palm of the hand or a brush. The skin is washed with soap and sodium carbonate solution (4 drams to the pint), in order to remove fat, and when dry the adhesive is applied *without* shaving the part.

[1] M. Sinclair, Major R. A. M. C.: "A Collection of Fracture Apparatus Used in the British Army."

Cover the area evenly and apply the ordinary four-ply gauze as it comes out of the packet, having roughly measured the requirements and gathered it in at the level of the wrist or ankle. An alternative method is to put on a length of "elastic cotton net bandage" (S. Maws) from knee to ankle, glue it on the *outside*, and then apply the gauze as above and bandage carefully with a thin bandage.

The gauze being spread out fan-shaped, adapts itself to the conformity of the limb and is kept in apposition with the skin by a loose woven bandage. The extension can be made almost immediately.

The above method of extension is a very great saving of time and when compared with the cost of good strapping is as twelve cents to seventy-five cents per limb.

A slight modification in the above formula gives an excellent adhesive which is a little more elastic.

Isinglass	50 parts
Glue	50 "
Water	50 "
Calcium chloride	2 "
Tannic acid	12 "
Thymol	1 "
Glycerin	2 "

PORTABLE SUSPENSION FRAME.

Various forms of suspension (so-called Balkan) frames have been devised for the treatment of fractures and other affections requiring suspension and extension. Of these, the one which allows the most accurate adjustment is that exhibited at the War Demonstration Hospital of the Rockefeller Institute. (See Figs. 110 to 118.) This will probably be supplied to the army hospitals. A simpler type of construction and one requiring less material is that illustrated in Fig. 119. The simplest type is made with a single upright at each end, to which the upper horizontal bar is fastened.

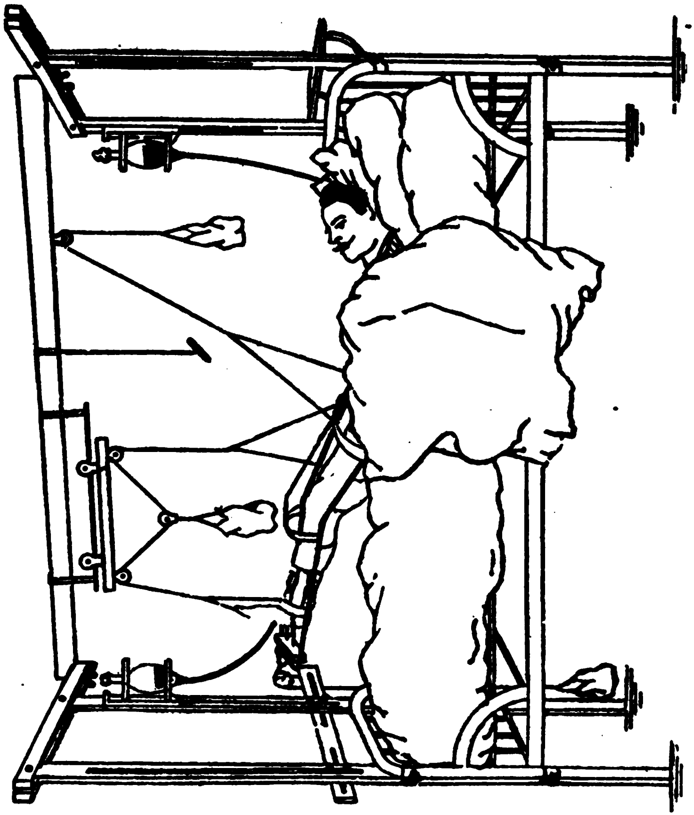

FIG. 110.

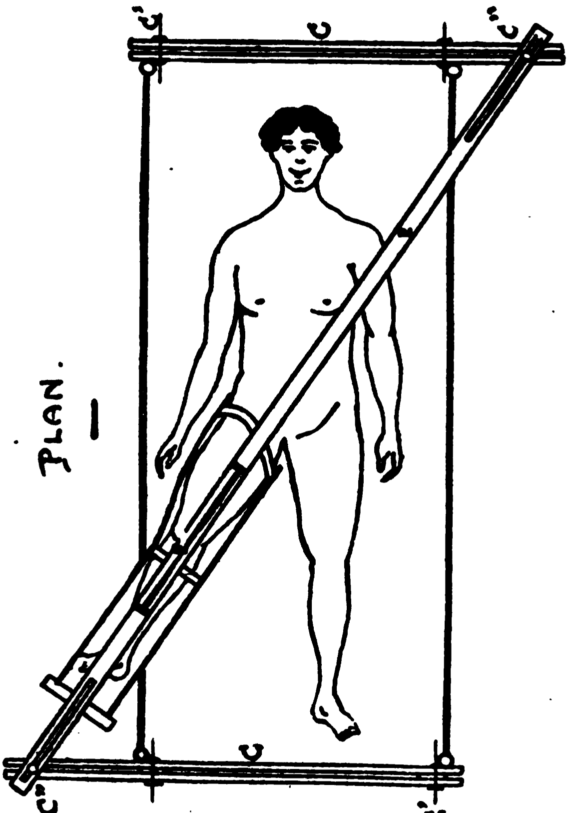

FIG. III.

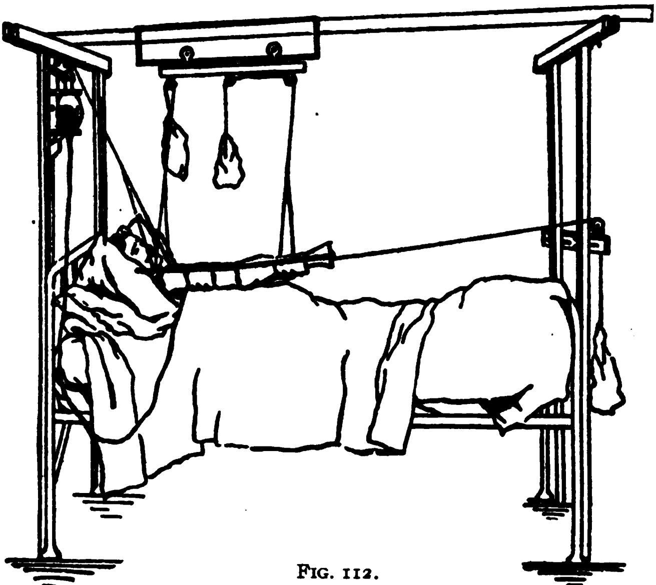

FIG. 112.

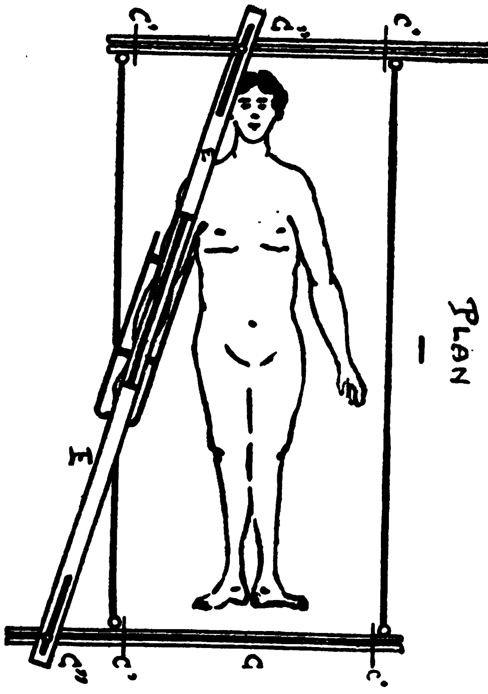

FIG. 113.

HEAD END OF FRAME

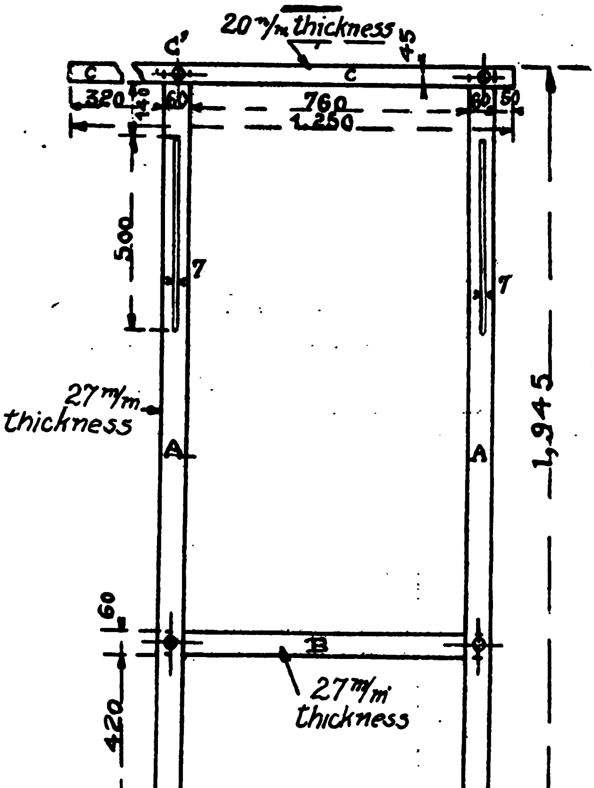

FIG. 114.

FOOT END OF FRAME

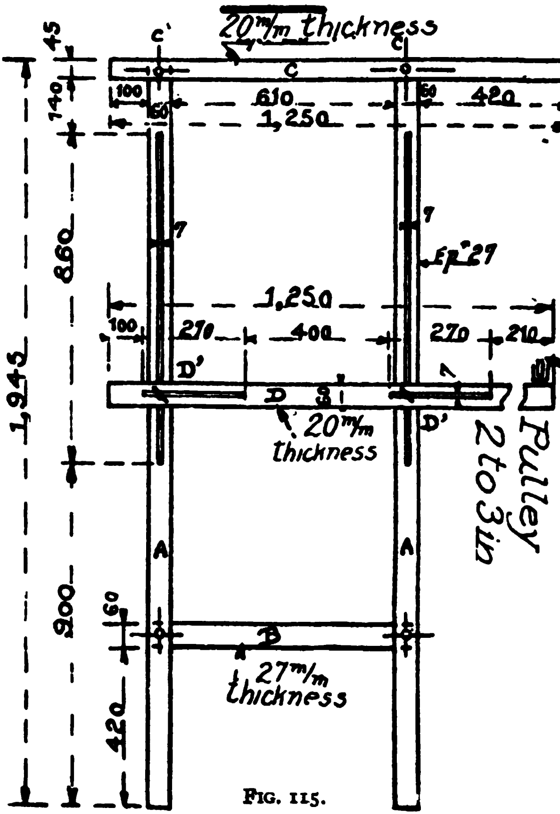

FIG. 115.

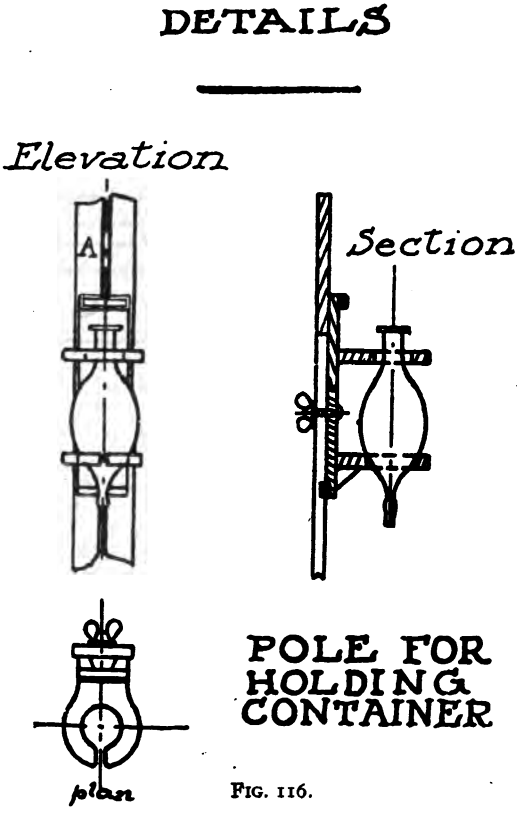
DETAILS
Elevation
A
Section
plan
POLE FOR
HOLDING
CONTAINER

FIG. 116.

DETAILS

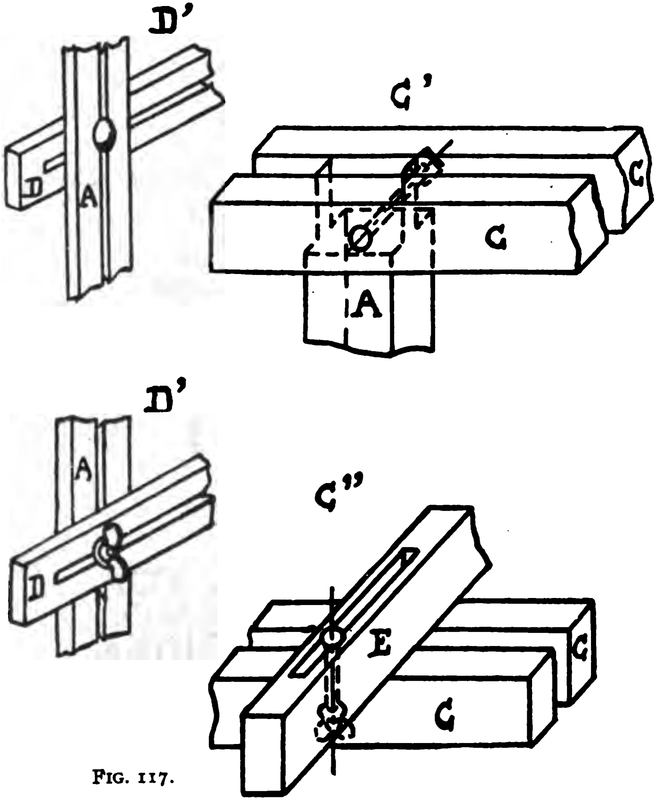

Fig. 117.

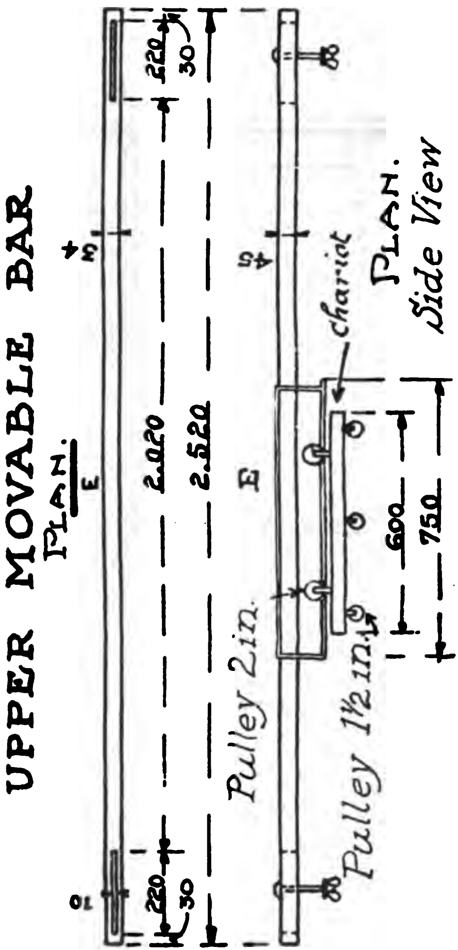
UPPER MOVABLE BAR
PLAN.
E
34
220
30
2.020
2.520
220
30
10
45
E
Pulley 2 in.
chariot
Pulley 1½ in.
600
750
PLAN.
Side View

FIG. 118.

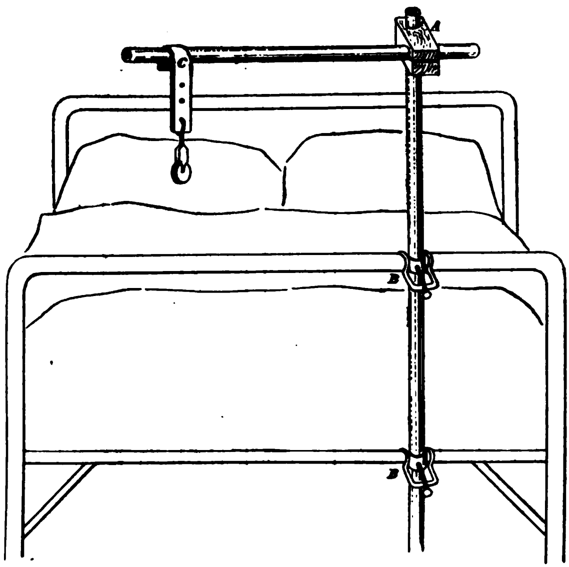

FIG. 120.—An excellent traction attachment, or Balkan frame, may be made with the Maddox unit clamps and bed-frame clamps and iron pipe. In the traction apparatus shown in the above illustration the parts are as follows:

A. Maddox clamp.
B. Bed-frame clamp.
C. Hook and pulley.

The Maddox clamp is also of value for the quick construction of Bradford frames.

1
2
2
2

1
2
2
1
2
3
2
2
2
3
3
1
1
1
1
1
1
3
3
1
2

40

APPENDIX.

EQUIPMENT AND MATERIALS IF NO REGULAR ORTHOPÆDIC APPLIANCE SHOP IS AVAILABLE

EQUIPMENT.

Bench, work and chest (see cut) (not supplied at present)	1
Chisels, cold, $\frac{1}{4}$-inch	2
Chisels, cold, $\frac{3}{8}$-inch	2
Chisels, cold, 1-inch	2
Clamp, splicing lineman's 5 holes, $\frac{9}{64}$ths to $\frac{19}{64}$ths inch, Irvington Co., or equivalent	1
Clamps, malleable iron, 4 inch	2
Countersinks, $\frac{5}{8}$-inch, to use in breast drill	2
Drill, breast, Miller's Falls, 3-jawed chuck, No. 12, or equivalent	1
Drills, Morse, for same, $\frac{3}{16}$ and $\frac{1}{4}$-inch	2
Files, flat bastard, 10-inch, with handles	3
Files, flat, second cut, 10-inch, with handles	2
Files, round, bastard, 10-inch, with handles	2
Files, round, bastard, 6-inch, with handles	2
Files, flat, second cut, 6-inch, with handles	3
Files, saw (three-cornered), 6-inch, with handles, medium cut	3
Hammer, machinist's, 1-pound, cross pein	1
Hammer, machinist's, 5-ounce, ball pein	1
Lead, block 2 x 3 x 4 inches	1
Pliers, button pattern, 10-inch, Utica 1000, or equivalent	1
Pliers, heavy for cutting wire, 12-inch Nettleton nippers	1
Punch, belt, universal, 6 size	1
Punches, center, 4-inch	3
Punches for $\frac{1}{8}$, $\frac{3}{16}$, $\frac{1}{4}$ rivets	3
Rasp, wood, 10-inch, half-round	1
Reamer, 6-inch, one-quarter at large end for breast drill	2
Rod, round, soft iron, 8.32 diameter, straight, about 12-inch lengths, by the pound	40
Rod, round, soft iron, 10.32 diameter, straight, about 12-inch lengths, by the pound	20
Rule, box-wood, 24-inch folding	1

Rule, caliper, 6-inch, 1 fold	1
Saw, fine miter, 12-inch back saw	1
Saw, hack, extension, with 12 blades, 8-inch, 18 teeth to inch, Miller's Falls or equivalent	1
Shears, tin snips, Lyon pattern, 14-inch	1
Solder, in pounds	2
Soldering iron, 3 pounds, with handle	1
Soldering salts, in pounds	¼
Stone, fine carborundum, 5 x 2, in box	1
Vise, bench, 3½-inch jaw, solid jaw, swivel base, Reed, No. 203½, or equivalent	1
Vise, hand, 1½-inch jaw	1
Wrench, monkey, 10-inch, Trimo or equivalent	1
Wrench, pipe, 12-inch, Trimo or equivalent	1
Yankee plain screw-driver, No. 90, size 3-inch	1
Yankee plain screw-driver, No. 90, size 10-inch	1

MATERIALS.

Aluminum, sheet, 16 gauge, standard size 12 x 72 inches, by piece	12
Bolts, brass, stove, 3/16- x ½-inch, by gross	3
Bolts, brass stove ¼- x ¾-inch, by gross	3
Buckles, iron, sliding bar type, 1-inch, by gross	1
Buckles, iron, sliding bar type, 1¼-inch, by gross	¼
Buckles, iron, sliding bar type, 1½-inch, by gross	½
Copper, hot rolled sheet, 20 gauge, standard size 30 x 60 inches, by piece	1
D rings, 1-inch. brass, by doz.	3
Duck, cotton, khaki colored, 29 inches wide, by yard	25 to 30
Elbows, brass, 1-inch, 90° angle, 5/16 hole, by doz.	3
Escutcheon pins, brass, No. 12 x ⅝ long; No. 14 x ⅝ long; No. 16 x ⅞ long; by pound each	1
Iron, strap, black, soft, ½ inch wide; ¼ inch thick, 10-ft. lengths, by piece	10
Iron, sheet block, open hearth, 20 gauge, in ½ sheets, 48 x 24 inches, ½ sheets	8
Leather, calf skin, by skin	1
Leather, first-grade strap, about 4 ounces, by side	½
Leather, first-grade strap, about 8 ounces, by side	½
Rivets, soft iron, ⅛-inch, 3/16-inch, ¼-inch, lengths ½-inch, ¾-inch, 1-inch, by pound each	1
Rivets, copper, ⅛-inch, 3/16-inch, ¼-inch, lengths ½-inch, ¾-inch, 1-inch, by pound each	1

Snap hooks, harness, with flat steel tongues and flat steel noses, $1\frac{1}{4}$ inch, iron (North & Judd), by doz.	3
Tin, sheet, 24-gauge, 20 x 28 inches, by plate	6
Webbing, 1-inch, by yard	72
Webbing, $1\frac{1}{4}$-inch, by yard	36
Webbing, $1\frac{3}{4}$-inch, by yard	36
Wire, copper, $\frac{1}{16}$-inch, by 1 pound spools	1
Wire, Bessemer steel, copper-coated, $\frac{3}{32}$ diameter, straight, about 6-foot lengths, by pound	20
Wire, Bessemer steel, copper-coated, $\frac{6}{32}$ diameter, straight, about 6-foot lengths, by pound	20
Wire, Bessemer steel, copper-coated, $\frac{8}{32}$ diameter, straight, about 6-foot lengths, by pound	40
Wire, Bessemer steel, copper-coated, $\frac{10}{32}$ diameter, straight, about 6-foot lengths, by pound	20
Wire gauze, 5 x 36 inches, by doz.	4

* Field Chest and Work Bench with Adjustable Legs.

Designed by Major Robert D. Maddox, M. R. C., U. S. A.

A chest constructed of hard wood throughout, top to be of maple, 42 inches long, 18 inches wide, $1\frac{1}{4}$ inches thick, securely fastened to sides by angle-iron straps, 2 x 2 x $\frac{3}{16}$ inches, screwed to top and sides. A shoe of the same size angle iron screwed along ends of bottom of chest. The legs are detachable, 32 inches long, 2 x 3 inches, and are fastened into place by $\frac{7}{16}$-inch bolts, passing through legs and screwed into tapped holes in angle iron. All corners of chest and drawers are to be dovetailed, and drawers are to have three equal spaced gains front and back, measuring $\frac{3}{8}$ inch wide and $\frac{1}{4}$ inch deep for sliding partitions. Dimensions of drawers inside: two upper drawers, 40 inches long, 21 inches wide, and $2\frac{1}{4}$ inches deep; one lower drawer, 40 inches long, 21 inches wide and $8\frac{1}{4}$ inches deep. Partition between drawers to be gained into sides $\frac{1}{8}$ inch and securely fastened; holes to be bored in the top and counter-sunk on bottom side; to provide means of holding vise to top of bench, a piece of iron $\frac{3}{32}$ inch thick, 10 inches wide, and 14 inches long is to be screwed to lower right-hand corner of bottom drawer, on which to fasten vise when packed. Drawer handles are to be of iron, bolted through drawers, and heavy chest handles

* Not supplied at present.

are to be securely fastened on each end of chest. This chest is intended to carry tools furnished in the above outfit, together with all small materials. It can be set up in a few minutes, and when taken down the legs packed in the lower drawer.

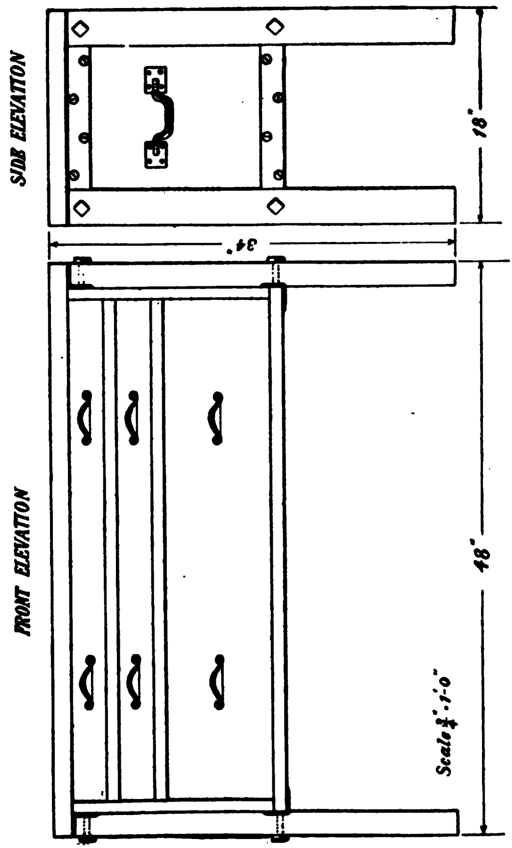

FIG. 121.

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